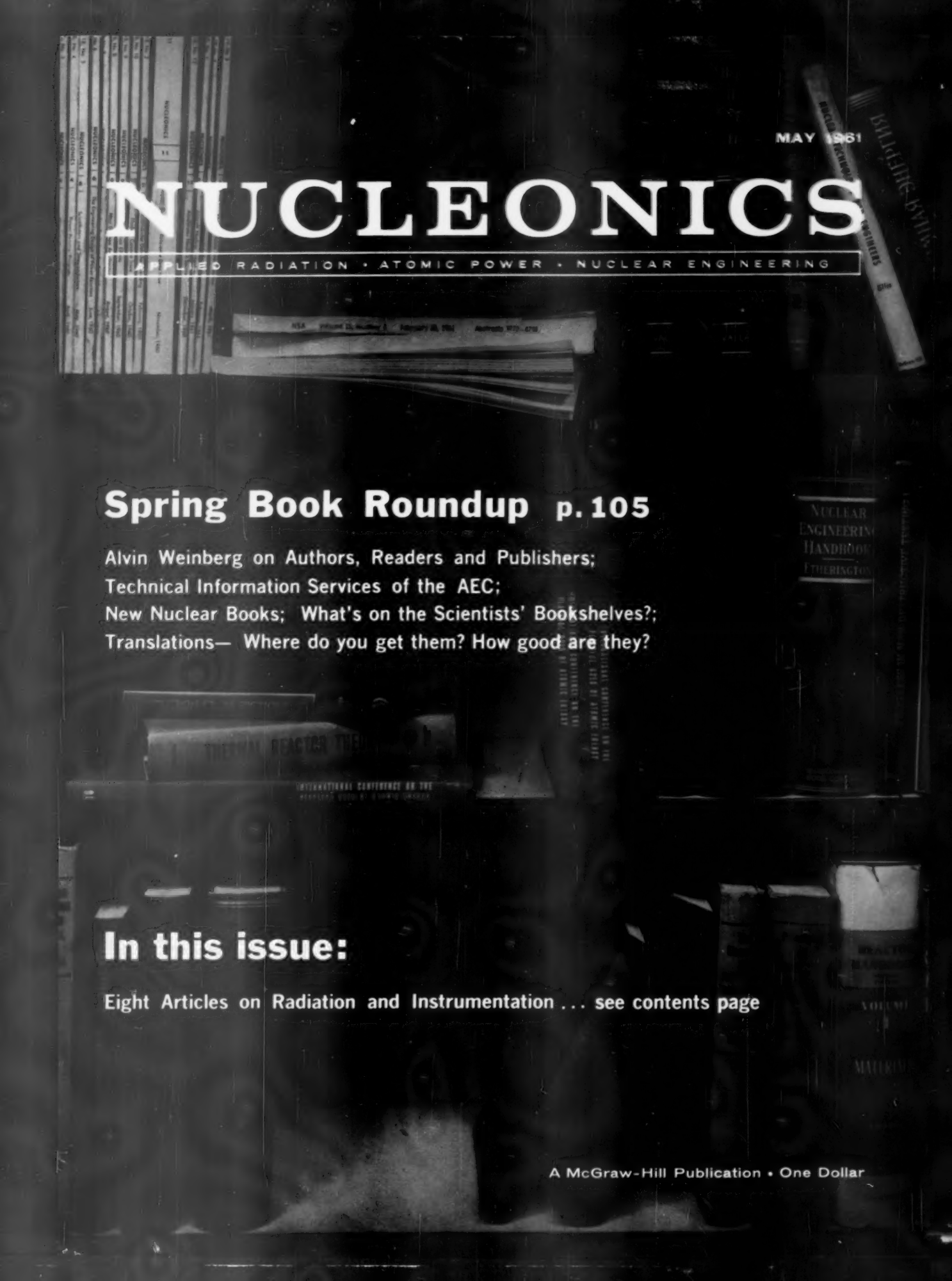


MAY 1961

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

Spring Book Roundup p. 105

Alvin Weinberg on Authors, Readers and Publishers;
Technical Information Services of the AEC;
New Nuclear Books; What's on the Scientists' Bookshelves?;
Translations— Where do you get them? How good are they?

In this issue:

Eight Articles on Radiation and Instrumentation . . . see contents page

A McGraw-Hill Publication • One Dollar

X-RAYING LARGEST STAINLESS STEEL "HOT" PUMP CASTING

Above, technicians mark segment of casting for one of many hundreds of X-ray pictures employing a 24,000,000 volt Betatron at the Bonney Floyd Foundry. *Below*, X-ray picture is carefully inspected for flaws.

Shown here is the largest single-piece stainless steel pump casting built today. The X-ray procedure is just one of the many inspections necessary to assure the high quality in Worthington nuclear pumps. Special designs were necessary to allow a single casting to be made for this size pump.

A more complete discussion of special equipment criteria and manufacturing techniques for nuclear requirements is available in a Worthington pamphlet, "Manufacturing For a Nuclear Power Plant." Ask for RP-1092.

To provide the special attention required to engineer and manufacture nuclear products, Worthington has an Advanced Products Division which specializes in pumps and other equipment for nuclear plants. For further information, write Worthington Corporation, Nuclear Department 106-7, Harrison, New Jersey.

WORTHINGTON

PRODUCTS THAT WORK FOR YOUR PROFIT

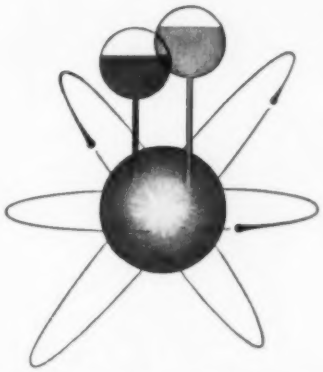
B&W Spectral Shift Control Reactor

...an important step toward LOWER NUCLEAR POWER COSTS

The Babcock & Wilcox Company presents a high capacity reactor which incorporates significant improvements in neutron economy, power distribution within the core, and core lifetime. The Spectral Shift Control Reactor (SSCR) is the outgrowth of extensive research and engineering on the time-proven pressurized water concept. It operates with a mixture of heavy and light water which shifts the neutron spectrum so as to control resonance absorption in the fertile material during the life of the core. As the reactor is operated, the addition of light water makes neutrons available to sustain criticality for substantially increasing core lifetime.

NEUTRON ECONOMY

The excess mass of fuel required for long core lifetime is controlled by heavy water instead of neutron-absorbing materials, such as control rods or soluble poisons. In fact, at full power the SSCR operates with most of its control rods completely withdrawn. Neutrons which in other reactors would be wastefully absorbed in control rods, or soluble poisons, are instead absorbed in the fertile material to produce new fuel. Conversion ratio is improved for both thorium and low enrichment uranium cycles, resulting in extended core life. A breeding ratio greater than unity may ultimately be achieved with recycled U-233 fuel. The inherent neutron savings alone in the SSCR make it an important



step toward the achievement of economic power.

POWER FLATTENING

In other water reactors, control rods in the core distort the power distribution. The reduced number of rods in the SSCR core provides the highest degree of power flattening available in any reactor today over the entire core life. For this reason, the SSCR core can produce substantially more power than other reactor cores of comparable size. Substantial savings in unit capital costs of the reactor primary loop, shielding, and containment are thus achieved.

LONGER CORE LIFE

The ability of D_2O to hold down excess reactivity permits a high initial fuel loading which allows core lifetime to be extended far beyond the margins presently imposed by material limitations. Since irradiation damage to oxide fuels appears to be inconsequential, lifetimes of future cores may be limited only by neutron absorption in the fission products themselves.

FLEXIBILITY

The SSCR can control various amounts of excess reactivity permitting ready adaptation to future cores that have the optimum combination of fuel type enrichment and cladding. Benefits from the thorium-uranium 233 fuel cycle, when it is developed, can be immediately attained.

Recently, the Atomic Energy Commission awarded to B&W a million dollar contract for critical and exponential experiments on the mixed water moderator principle. The information obtained will be valuable in furthering the development and application of all reactor designs utilizing mixed moderators, including the SSCR. The combination of the Spectral Shift Control concept with the advanced technology of the pressurized water reactor yields one of the most advanced nuclear power reactors that can be offered to the utility industry today. The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, New York.

Physicists, metallurgists, radio chemists and reactor engineers will find opportunities to work on this and other interesting reactor concepts at B&W. Address inquiries to W. F. Porter, Personnel Manager, Atomic Energy Division, The Babcock & Wilcox Company, 1201 Kemper Street, Lynchburg, Va.; or phone collect, VIctor 6-6521.

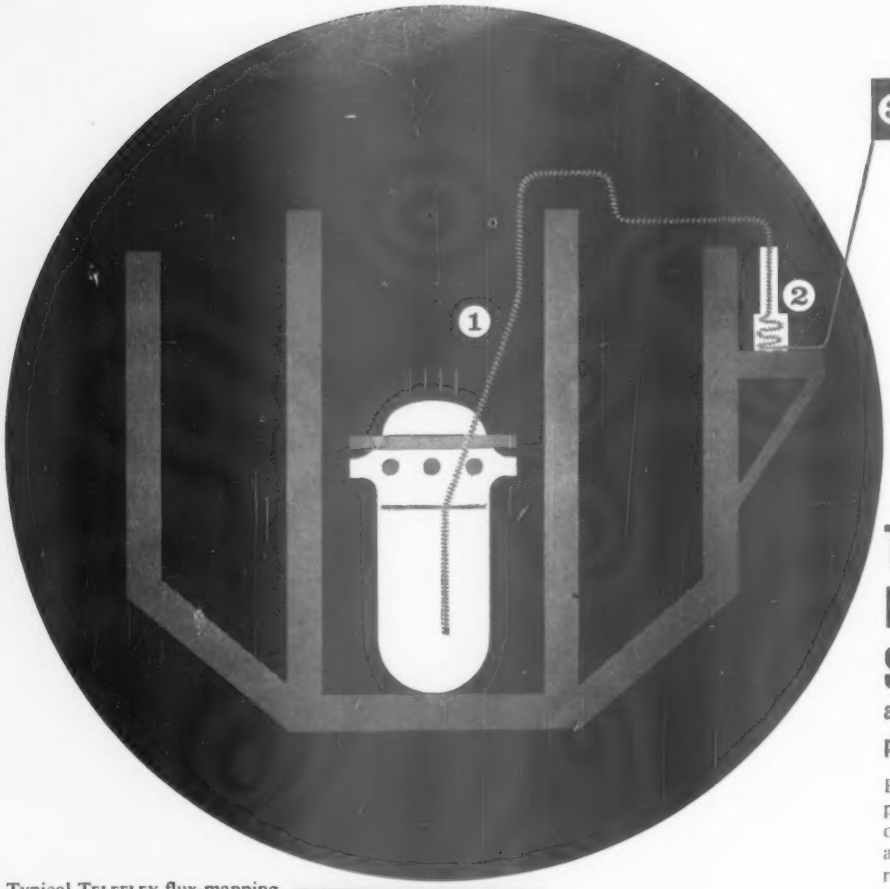
B&W

THE BABCOCK & WILCOX COMPANY

NUCLEAR POWER APPLICATIONS

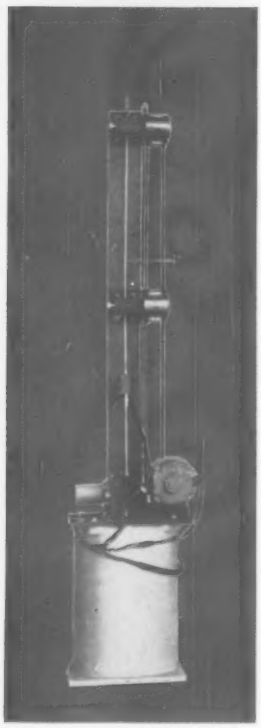
AE 83

Vol. 19, No. 5 - May, 1961

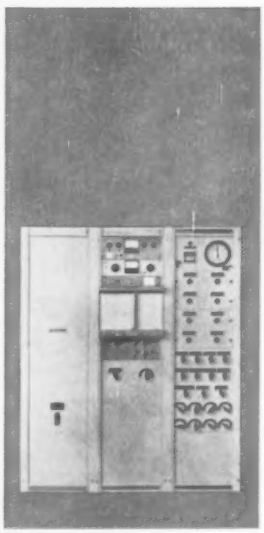


Typical TELEFLEX flux-mapping system, originating and remotely controlled from the safe vantage point of the main station control room.

1. TELEFLEX helical flexible cable provides accurate and positive remote positioning of flux wires.



2. Electro-mechanical drive comprised of specially-hobbed wheel, gearmotor and compact cable-storage magazine.



3. Remote control system includes counters, readout and recording devices; may be located anywhere.

TELEFLEX FLUX-MAPPING SYSTEMS give speedy, accurate core observations, power distribution control

Every feature of the TELEFLEX System points toward more effective control of reactor power capability. This advanced system produces accurate, reliable flux level measurements, and quickly . . . a complete map can be obtained in approximately one hour. As a result of more exact understanding of fuel burnup and control rod programming, more economical refueling techniques and more efficient core power distribution at all power levels is possible.

The TELEFLEX System is a proved electronic-mechanical package, completely integrated and automatic. The principal component is TELEFLEX flexible cable, providing the means for unlimited accessibility to remote, normally inaccessible areas. The TELEFLEX System inserts flux wires into core thimbles, regulates wire exposure, automatically retracts exposed wires, passes irradiated wires through a counter-readout device, records activity of each wire and its accurate location.

The TELEFLEX System is basically simple, and lends itself to many reactor design configurations. Possibilities have by no means been exhausted. For some idea of all that TELEFLEX has to offer you, get in touch with TELEFLEX nuclear-trained engineers and research people.

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NUCLEAR PRODUCTS DIVISION
NORTH WALES, PENNSYLVANIA

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

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...about NUCLEONICS

A Change in Command

One of the toughest jobs in the publishing business is being a managing editor. A managing editor must be at once tough and gentle. In running a staff and "getting the book out," he must be demanding of top performance and yet understanding of human frailty. He must (on NUCLEONICS) know his field and, at the same time, all the intricacies of magazine production. He must know how to meet tight schedules and to hold production costs down. He must be an expert in the art of communications. And he must know the audience his magazine is serving, its subscribers.

This is a big order for any one man. We on NUCLEONICS have been fortunate over the years in always having had managing editors who have filled this bill. In fact, we are just losing one who fits the description superbly. Dr. Daniel I. Cooper, who was in that spot for four years and with NUCLEONICS for seven, has resigned to take another job. We will miss him and wish him well.

His post will be taken by another capable physicist, Dr. R. Hobart Ellis, Jr., an Associate Editor on NUCLEONICS who has done a fine job with us for five years. Hoby has been responsible for seeing that the pages of NUCLEONICS are well stocked with good articles in the fields of applied radiation and instrumentation.

HOBY ELLIS takes over the job of managing editor of NUCLEONICS this month from Dan Cooper, who has resigned to take another job

He got his undergraduate degree at Bowdoin College and his PhD at Columbia, where he worked at the Radiological Research Laboratories on physics experiments related to the measurement of radiation dose. This research resulted in his writing a number of scientific papers, including two in NUCLEONICS in 1950. And he has carried his interest in writing to the endpoint for a wordsmith—he has written one book, "Nuclear Technology for Engineers," and is producing a second one, "Irradiation Technology." His familiarity with the nuclear field and the use of the English language bodes well for NUCLEONICS' readers.

Let's Get Reading!

In view of the growing importance of nuclear literature, we've enlarged our books section this month to 12 pages. We hope we are giving you some tools to deal with the piles of nuclear literature on your desk. Alvin Weinberg of the Oak Ridge National Laboratory has written a controversial article on the pros and cons of nuclear literature (we'll hear rebuttals to this article later). In addition, Edward Brunenkant and Richard Berg fill you in on how to use the AEC technical information service. And three NUCLEONICS surveys resulted in our article on translating foreign nuclear literature and the nuclear book lists from scientists and publishers. So let's get reading!

—The Editors

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COMING FEATURES

Radiometric Chemical Analysis

Components for Nuclear Reactors (July)

X-Ray Fluorescence Spectrometry

Radiation Chemistry (October)

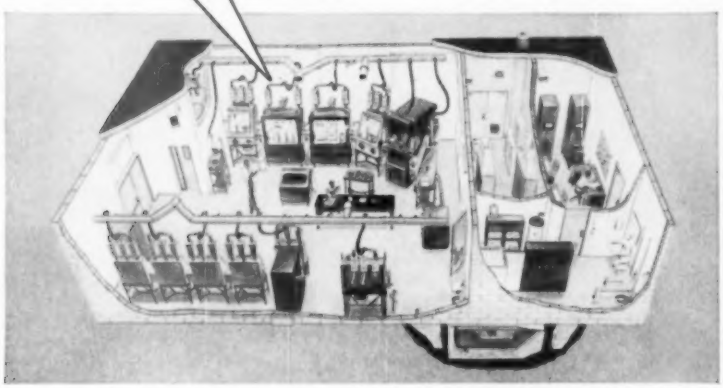
CURIUM-242 for Direct Conversion Generators

Development of direct conversion systems at The Martin Company includes the application of thermionic techniques as well as the thermoelectric techniques used in current SNAP programs. Thermionic generators seem particularly promising for space applications. This work has emphasized the need for an isotopic heat source of high power density which remains stable at the high operating temperatures (1500°K) required for thermionic diodes.

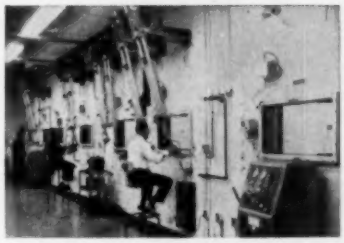
Curium-242 is an ideal power source because of its high power density, its potentially lower cost and the relative ease with which its alpha-particle emission can be shielded. While Polonium-210 and Curium-242 have equal power densities (100-120 watts per gram), Polonium compounds lack high temperature stability. Curium oxide (Cm_2O_3) melts in the neighborhood of 1800°K.

Recognizing the need for high temperature heat sources, Martin has undertaken, under contract with the U.S. Atomic Energy Commission, to "scale up" Curium-242 production on a multi-*gram* level. Discovered in 1944, Cm-242 had only been made in tracer amounts until 1960 when the University of California's Livermore Laboratory produced it on a 250 mg scale.

"Scale up" of the process has involved several challenging problems. For example, excessive peroxide formation in solutions above 0.02M Cm-242 complicates the chemical reactions. In solutions above 0.07M, heat evolution itself becomes limiting. This localized high energy release dictates special techniques for ion exchange, precipitation and handling of Curium compounds.



Martin-Nuclear Heavy Element Processing Facility, Baltimore, Maryland



Martin hot cell facilities, Quehanna, Pennsylvania

The production process, under direction of the Nuclear Chemistry Department at Martin's Nuclear Division, begins in the Heavy Element Processing Facility now in operation at Baltimore. This facility is capable of purifying 100 grams of Americium-241 at one time and encapsulating individual aluminum targets each containing 4 grams of AmO_2.

The Americium-241 targets will be irradiated at fluxes exceeding 10^{14} n/cm²/sec at the AEC National Reactor Testing Station in Idaho. After irradiation, each target will yield about 1.5 grams of Curium-242.

Remote chemical purification of Curium-242 by ion exchange techniques and conversion into high melting point compounds for use in direct conversion systems will be accomplished at the hot cell facilities operated by Martin at Quehanna, Pennsylvania.

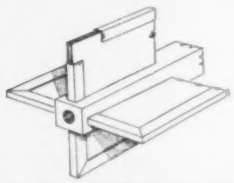
Martin Heavy Element Processing Facility-Baltimore
AEC National Reactor Testing Station, Arco, Idaho
Martin Hot Cell Facilities, Quehanna, Penna.
CRUDE AmO2
Purification & Target Preparation
AmO2 TARGET
Irradiation (100 days) Cooling Period (30 days)
IRRADIATED TARGET
Curium-242 Separation, Purification-Conversion
Cm2O3 PELLETS

MARTIN

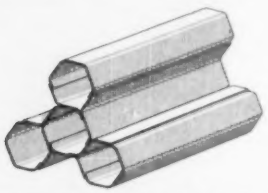
an effective material for neutron shielding

Boral is a uniform dispersion of boron carbide crystals in aluminum. Its high boron carbide content (up to 50%) enables it to absorb thermal neutrons without the production of hard gamma rays.

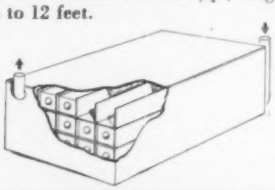
Boral Plate can be worked to meet the requirements of a wide range of shielding applications. It can be drilled, tapped, punched, sawed, sheared, formed, and welded. The accompanying sketches show typical designs and assembly methods.



Shut-down Control Rod for Reactors
Assembly of this unit is made by arc welding. All edges of Boral Plate are clad. The center bar is tapped to receive the threaded rod.



Storage Cells for Fresh Fuel
Cells are usually used in assemblies of several fuel units, encased in aluminum or stainless steel cylinders. The Boral shapes should have corner radii of ¾"; length can be up to 12 feet.



Water-cooled Boral-lined Case for Spent Fuel Elements
This Boral-lined aluminum case with egg-crate type separators for the transportation and storage of spent fuel units, is assembled from Boral Plate by arc welding.

Typical and Potential Applications
Reactor shields, neutron curtains, shutters for thermal curtains, safety rods, storage and shipping containers for fissionable material, fabricated boxes for radiation-sensitive devices, protective shields for easily activated components.

Brooks & Perkins, the first commercial producer of Boral, invites you to send for technical data and literature. 60-T-11

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NUCLEAR REACTIONS

Bacteria in Reactor D_2O

DEAR SIR:

The presence of bacteria in nuclear reactor light-water cooling circuits has been reported by Fowler et al.* and Ophel.†

During the last eighteen months regular microbiological examinations have been carried out on both the heavy- and light-water cooling circuits of the high-flux, heavy-water-moderated research reactor HIFAR at this establishment. The heavy-water circuit provides an interesting opportunity for the study of micro-organisms because of the high isotopic purity (greater than 99.6%), the high chemical purity (ensured by constant passage through a mixed-bed ion-exchange column), and the presence of a helium gas blanket over the surface of the heavy water in the reactor tank. Furthermore, during its passage through the reactor core the heavy water is subjected to intense irradiation, the neutron flux being approximately 10^{14} n/cm²/sec.

The presence of bacteria in the heavy-water circuit has been observed at all stages of HIFAR's operating cycles. Several different organisms have been isolated including members of the genera Pseudomonas, Archromobacter and Bacillus. The viable count of organisms varies in different parts of the circuit and at different stages of the operating cycle from 0–1 organisms/ml, after passing through the central aluminum tank during reactor operation at 10 Mw, to 18,000 organisms/ml in water emerging from the ion-exchange bed.

It is interesting to note that in parts of the circuit not subjected to intense irradiation an *increase* in the viable count follows the commencement of each operating cycle. This suggests that the reactor operation—possibly by its action on the ion-exchange resin—releases nutrients into the heavy water.

A full account of these experiments will be published elsewhere.

—P. S. DAVIS, G. G. MCPHERSON
Chemistry Section
Australian Atomic Energy Commission Research Establishment
Lucas Heights, N.S.W. Australia

DEAR SIR:

With regard to the "*increase* in viable count" following "commencement of each operating cycle," here at LASL we grew the isolated Pseudomonas species on a distilled-water suspension of resin from the ion-exchange columns. This, of course, was in the absence of a continuing radiation effect. It was also our belief that the resin served as a source of metabolites. However, we assigned the metabolites to chemical degradation from regeneration rather than to radiation degradation. In all probability the metab-

* E. B. Fowler, NUCLEONICS **18**, No. 4, 102 (1960).
† I. L. Ophel, NUCLEONICS **18**, No. 10, 6 (1960).

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olites arise from a combination of both factors.

—ERIC B. FOWLER
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Chemonuclear Fuel

DEAR SIR:

Reading the February, 1961 issue of NUCLEONICS, I came across the article on p. 48: "Thin Unclad Fuel Needed for Chemonuclear Reactors."

May I complete the list of well known ideas for such thin unclad fuel with the summary of a German patent [given below], which describes a fuel for chemonuclear reactors or for a power-reactor superheater.

Different from the Harteck-Dondes glass fuel fiber, my new porous system holds the fuel only on the surface of metallic fibers. While the UO_2-glass fiber burns out and can break or be pulverized, the metallic fiber holds together even if the fuel on the surface is fully used up.

The sintered-metal fibers will have some other aspects in the future.

—PETER FABER
Kahl am Main
Germany

German Patent 1,037,607 (issued to Elektrizitats-Actien-Gesellschaft vorm. W. Lahmeyer & Co., Frankfurt/Main; inventor: Peter Faber): Fuel material is deposited in thin layers (of the order of hundredths of a millimeter) on the surface of a supporting material. The latter can be in the form of fibers, chips, wire, wool, etc. and made of metallic (e.g., aluminum, magnesium or zirconium) or glass-like materials. The deposition process can be a known method such as vacuum-vaporization, electro- or electrochemical deposition. The fuel deposit can be in metallic or metalloidic form or chemically combined to the base metal as UO_2.

The fuel layer must be thin enough to permit fission-product escape. Thus, the fission products could be washed out with the coolant without breakdown of the bond between the fuel and supporting material. Thereby, a substantially higher fuel utilization is possible compared with that of present fuels. Moreover, a higher thermal efficiency can be attained because of the large surface of a fiber structure and because there is no material separating the fuel from the coolant.

Also, the flexibility of a fiber structure is advantageous. The fuel can operate at higher temperatures without thermal stresses.

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E. G.

Fort Belvoir reactor training simulator . . . normally in operation 24 hours a day . . . no regularly scheduled maintenance time . . . maintained by RCA on yearly contract basis . . . results: *better than 99 per cent of scheduled training time is productive time!*

Realizing the increasing importance of nationwide service facilities, many prominent manufacturers* of nuclear and scientific equipment have contracted with RCA Service Company as an approved service representative for their products.

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- **Complete facility operation**
- **Specialized engineering assistance**
- **Training and publications**

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*Names available upon request

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LEAD

Pb

NEW YORK, May 1 -- MORE THAN 25 MILLION POUNDS OF ASARCO CAST AND ROLLED LEAD HAVE BEEN USED FOR RADIATION SHIELDING IN PERMANENT AND MOBILE NUCLEAR REACTORS SINCE THE BEGINNING OF THE ATOMIC POWER ERA.

ASARCO

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Launching an atomic powered submarine with Asarco radiation shielding aboard. Inset shows method of anchoring the sub's lead shielding plates with Asarco lead wool.

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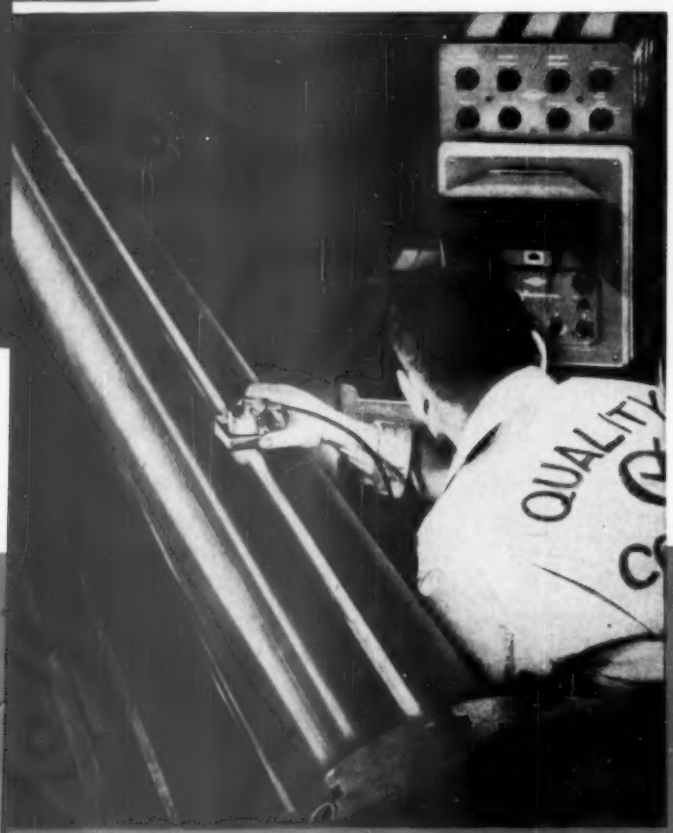

PIPE BEING ULTRASONICALLY TESTED IN ACCORDANCE WITH MILITARY SPECIFICATION MIL-T-18063A (Ships)

SIZE RANGE
DIAMETER—8" through 28" O.D.
WALL—½" to 4"
LENGTH—Up to 22 feet

TYPES OF STAINLESS
Austenitic grades, including E.L.C.

*** U. S. NAVY SERVICE APPLICATIONS FOR HYDROFORGED STAINLESS INCLUDE:**

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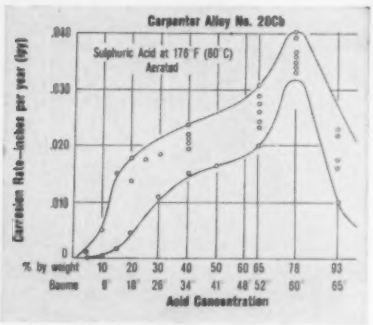
❷ Better corrosion resistance



The wide range of stainless steels available offers you the exact degree of corrosion resistance necessary for almost any corrosive environment. For mild corrodents, Carpenter No. 1 (Type 410) can be used; for extremely severe corrodents such as hot sulphuric acid solutions, Carpenter No. 20Cb should be specified. For other corrodents, one of the many other stainless steels will be the most economical material for you to use.

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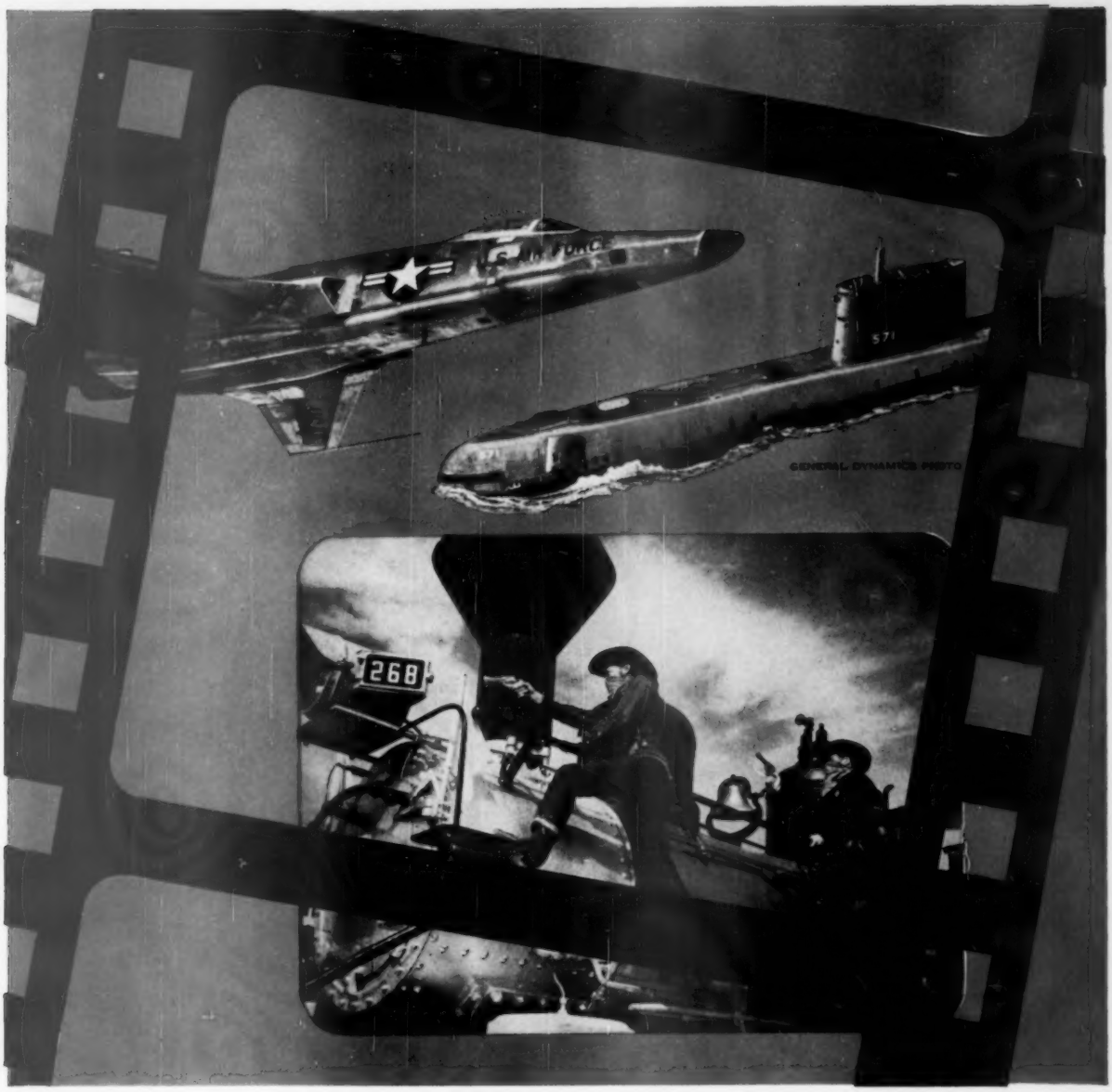

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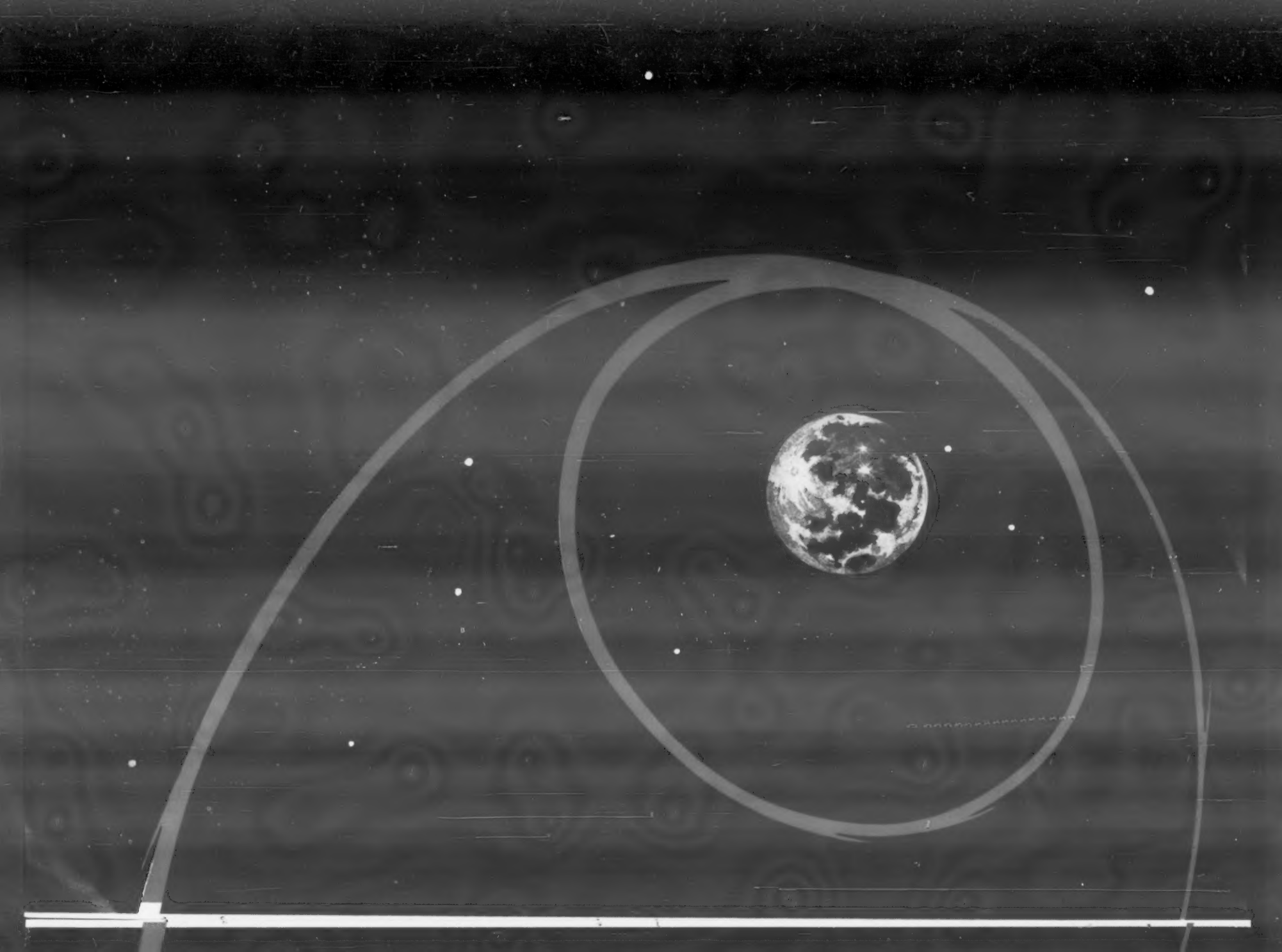

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Industry Drafting Counter-Proposal on Site Criteria, but . . .

Disapproval of AEC's proposed guides to reactor siting by a group of nuclear industry leaders* has led to establishment of an ad hoc group to try to draft a set of siting criteria as a basis for a counter-proposal (and as a more constructive approach than merely criticizing AEC's draft). This action arose out of a discussion meeting on AEC's proposed guides to reactor siting, held at the Atomic Industrial Forum in New York, March 17 and attended by 21 representatives of manufacturers, utilities and architect-engineering firms.

The meeting was held to give industry people having questions about the guides an opportunity to pose them to an AEC official. A morning session brought together industry people only, while Clifford Beck, AEC's assistant director of licensing and regulation for nuclear facilities safety, participated in the afternoon discussion.

Consensus of the industry group was that while they were labeled only a guide rather than a set of rules, AEC's attitude seemed to be that this is "the book." Furthermore, the industry people are worried that—while the guide implies that engineering improvements in the safety field may serve as a counterbalancing factor to minimize exclusion distances otherwise required—AEC staff seems to feel that there is no substitute for distance. Such an attitude would mean not only an aggravation of the cost problem of transmitting power from outlying areas to the load center, but also it would remove the incentive for improving safety engineering.

* J. L. Allen, Philadelphia Electric; Myron Beekman, Detroit Edison; Roger Coe, Yankee Atomic Electric; Giovanni D'Arminio, Selni-Edisonvolta; Harold Etherington, Allis-Chalmers; James F. Fairman, Con Edison of N. Y.; Carl Gamertsfelder, General Electric; B. John Garrick, Holmes & Narver; John E. Gray, Nuclear Utility Services Co.; W. E. Johnson, Westinghouse; Kenneth Kasschau, Alco Products; R. W. Kupp, S. M. Stoller Associates; Robert L. Menegus, du Pont; G. R. Milne, Con Edison; Don Rees, Saxton Nuclear Experimental Co.; D. R. Shoults, General Electric; Chauncey Starr, Atomics International; Harold Vann, Jackson & Moreland; Hood Worthington, du Pont; Paul C. Zmola, Combustion Engineering; also Charles Robbins, Edwin A. Wiggin, Gerald Charnoff of the Forum.

Earlier Utility Survey Showed Little Concern on Siting, SL-1

Utility leaders were not very vocal last month about any misgivings they might have felt about AEC's proposed site criteria. Only a few in a sampling of power executives warned against carrying safety requirements to excessive lengths.

The utility leaders questioned feel that the SL-1 accident has had no effect on the utility industry's attitude toward nuclear power; and that the advent of utility acceptance of nuclear power on a broader scale is approaching steadily but cannot be rushed.

Some expressed resignation about a trend pushing nuclear power plants toward more remote sites, while others denied that there is such a trend, believing that as more experience is gained with power reactors, less remote sites will become available.

These were some of the principal conclusions of an informal NUCLEONICS survey on the present status of nuclear power and the extent to which it has been affected by the SL-1 accident and the recent buildup of the siting problem (NU, March '61, 23, 24). Approached in the survey were representatives of every utility having a major nuclear power project, some that are participating in a group project, and some with no involvement to date in installing nuclear generating capacity.

Here are highlights of the utility leaders' reactions:

1. Do you find AEC's new site criteria helpful? do you find them encouraging?

Most answers were on the theme that the criteria are helpful "to the extent that they mark a step in the right direction, because a written policy is better than an oral one"; "it's encouraging because it's not rigid and ironclad"; "they appear simply to clarify policies followed for some time: it is helpful to have them better defined, but they do not indicate basic changes"; "a move in the right direction." However none displayed anything approaching enthusiasm for the criteria. On the other hand, one said, "We regard this as a beginning . . . the guides are just a first step in the direction of a philosophy that is a good one; further refinements—that is, greater understanding between AEC and the utilities—should result in more definite criteria."

It was pointed out that not only were the criteria intended as *guides* rather than *rules*, but furthermore that the table of distances at which reactors should be located from centers of population (NU, March '61, 23) were not even part of the guides but rather part of the hypothetical example furnished as an appendix to the guides. Thus, these distances are considered to be that much less firm, that much more merely a point of departure.

But one respondent warned that the criteria, needed for planning guidance, are "a standard of judging, not of judgment—but once criteria become established there is a danger of their being considered as rules."

A minority found the criteria "somewhat negative." "They are going to have the effect of slowing down, and thus discouraging to that degree, the development of nuclear power generating plants," said one, "in fact this has already happened: heating plants are out of the picture with these new criteria." Commented another: "The new criteria appear unrealistic in the light that they were initiated under panic conditions, and secondly, that the belt can again be tightened at the least provocation. Little planning can be done under these uncertainties."

In summary, as one executive put it, "progress is satisfactory, and the problem is not to allow the AEC criteria to become hard and fast rules that cannot be changed or ameliorated with proper justification at later stages."

2. Do the terms of the criteria affect your company's future plans in any way? How?

Most replied "no" to this question —the companies that have nuclear power projects in the planning stage are still going ahead, and those hold-

ing back are deterred for other reasons, primarily economic; no evidence was uncovered of any utility dropping tentative consideration of an atomic project because of the site criteria.

On the other hand, a few voices did express concern that the criteria would have the effect of choking off some nuclear power projects that might otherwise have blossomed in future. "It is conceivable that future expansion of nuclear facilities could be curtailed," as one put it; "we can well see how these arresting characteristics could impede other utilities throughout the country in their nuclear construction or expansion programs." Declared another: "We don't think it will have any effect on current research-development projects, but it may prohibit the construction of prototypes now in the thinking stage."

3. A question on the mills/kwh penalty that observance of the site criteria might entail brought little light, nearly all respondents saying it was impossible to determine.

4. The effect of the criteria on research-development work in nuclear power was also believed to be negligible or "none whatsoever," although one comment stated that "rigid application of any criteria would have the effect of stifling research and development to a certain degree," and another, "These criteria will slow up research and development very drastically, to the point where it will be difficult to note any progress at all."

5. A question was asked whether AEC's safety philosophy would prove an insuperable obstacle to making nuclear power economic (the philosophy of attempting to hold reactor accidents to absolute zero, rather than to merely a reasonable minimum while accepting industrial risk as do the chemical, conventional electric power, and other industries).

Quite a few expressed the view that the criteria and the philosophy that gave rise to them are subject to change, and that "with more first-hand knowledge and experience, it is entirely possible we may have a whole new set of criteria"; "experience may reveal an acceptable compromise." "I don't think the present safety philosophy will seriously affect long-range prospects of nuclear power, because I'm sure it will be modified as experience is gained. I'm confident that it will be modified, loosened up." The only U. S. utility now planning its third power reactor project declared, "Site criteria are not an insuperable obstacle to economic nuclear power in the territory of the Pacific Gas & Electric Company."

But another sizable group betrayed restiveness at over-design for safety, and used some striking metaphors to make their point: "The utilities of the U. S. are extremely cognizant of their responsibilities in respect to public and employee safety . . . [but] these features can get out of hand—such as three emergency brakes on an automobile. Steps should be undertaken to eliminate these extraneous safety devices which only build up the cost and do nothing toward the end result." "Safety precautions are vital and essential, but they could be carried to a ridiculous extreme." "Right now we are asked to build safety factor on safety factor on safety factor, like being guarded by a policeman who's guarded by a policeman who's guarded by a policeman. As soon as we find out how safe these plants are we feel AEC will relax these requirements . . . " "SL-1 certainly indicates we are over-containing insofar as the environment is affected."

Another group contented itself with acknowledging that safety and a philosophy of designing against a maximum accident certainly does make nuclear power more expensive, but that it is impossible to foretell how great will be this obstacle in view of uncertainty about future trends in fossil-fuel costs, etc. Two respondents denied that the AEC philosophy is aimed at zero accident rate: "certainly the safety regulations are stringent, but I think part of the problem is due to lack of experience"; "we do not feel that AEC site criteria are, or have been, unreasonable, taking into account the relatively short period of experience."

6. Is nuclear power moving toward remote locations only, in your opinion? If so, will the economic use of nuclear power be delayed thereby? by how much?

Answers were fairly evenly divided between those who see it as "apparent that sites are becoming more and more remote," and those who deny this: "no, this is temporary until more experience is gained"; "I don't think that in the long run nuclear power plants will be moved strictly to remote locations because that would be a highly undesirable result"; "I don't think nuclear power is moving toward remote locations only. It shouldn't have to with the containment requirements that are now a part of that total picture." Commented PG&E, "There is nothing to indicate that future plants will be situated at places more remote from load centers than those already operating or under construction. We believe that satisfactory sites nearer to load centers will be found as experience increases and nuclear power plant technology advances. We believe that PG&E's development and utilization of pressure suppression containment is a significant step in this direction." Said LADWP, "Any site that had to be more than 30 or 40 miles from a population center would postpone nuclear power."

One final comment, putting a fresh twist on one possible effect of remote location, bears repeating: "I think the term 'remote' needs clarification. If you are really talking about 'remote' it seems to me you get into all kinds of problems. If you're talking 'remote' within the framework of the present site criteria the end result would be to lead utilities to build larger plants and these plants of course are more likely to produce economic power at an earlier date."

Only two respondents ventured a guess on the time period by which economic use of nuclear power might be delayed by remote siting. A LADWP official said, "If the site requirement went beyond 100 miles it could delay a plant by perhaps 4–7 years. But the regulations are not pinning us down in terms of mileage. And distance is not as important as the meteorological conditions." Another conjecture was "anything from 5 to 20 years—it depends on how remote 'remote' is." This re-

Criteria Feared by Japanese

An unusual perspective—from an unusual, external, vantage point—on issues usually assumed to be between only the U. S. government and U. S. industry, was given when two Japanese industrialists half-seriously lodged an appeal to AEC through NUCLEONICS not to adopt the reactor site criteria.

The industrialists, leaders of a traveling mission here to survey U. S. materials testing reactors (one an official of a leading Japanese utility, the other of a top Japanese reactor manufacturer), said they wanted to ask the U. S. government not to adopt the criteria because "the U. S. is the world leader in atomic energy; if the U. S. adopts these guides, the Japanese government would be very strongly influenced to adopt them also, and Japanese industry would be bound by them. And while we feel most U. S. companies will complain about their severity, their cause for complaint is not comparable with ours. Most of them will be able to find sites; for Japanese companies the only available sites in sufficiently low population zones would be in Hokkaido [Japan's north island, separated from Honshu, the main island, by Tsugaru Strait—and from the Tokyo area by some 500 miles]. In that case nuclear power would be almost prohibitive. For us it's a matter of life or death."

spondent went on to say, "The table doesn't really say you have to be terribly remote, but I'm afraid they mean they want to be more remote than the table says."

7. A question whether recent siting problems (Pt. Loma, Haskell Canyon, Jamestown, N. Y., Camp Pendleton) had affected utilities' attitudes brought the closest thing to unanimity in the survey: "no."

8. How has the SL-1 accident affected your attitude toward nuclear power?

Almost as unanimous a response of "no effect" came on this question. Several pointed out that the "design, construction and operation" of SL-1 were so distant from those of a central station power plant that there should be no effect on the power industry. "The Arco mishap isn't typical. It was an experimental operation," said a utility leader. "We will profit by the experience," remarked another; "it was a remarkably long time in the development of nuclear generating facilities before any accident occurred," said a third; "it again points up the necessity for better designs," said a fourth. The accident "was unfortunate, but in any new art accidents are bound to happen. It hasn't caused us to change our thinking, nor have we heard any protest to our nuclear plans because of the SL-1 incident," said one company planning its first reactor. On the other hand, a prominent abstainer from atomic power said, "Our wait-and-see attitude is strengthened."

9. Regarding the company's own plans for possible addition of nuclear-generated capacity, no surprises, no new incipient projects, came to light. Closest to a break was this, from Consumers Power Co. of Michigan, now halfway through construction of its first nuclear plant at Big Rock Point: "We will have to study the Big Rock Point project in its entirety before planning new nuclear activity. However, Consumers will have a cadre of trained people, it will have had the experience of putting a nuclear plant on stream, it will have gone through legal procedures and met AEC requirements. In other words, the company would be in an excellent position to take on another nuclear project."

Said LADWP (which just two months ago dropped its plan to build, with AEC, a 50-Mwe Improved-Cycle Boiling Water Reactor at Haskell Canyon, Calif.): "The Dept. of Water & Power is still anticipating going ahead with plans for a full-scale nuclear plant. We expect to have a complex of two or three units of 250 to 350 Mwe each. Our original thought was to have the first unit completed in 1967 or 1968. If we can keep the site within 100 miles of the population center it is still possible that we could hit within those target dates."

FINISHED FERMI FAST BREEDER: Many survey respondents mentioned importance of forthcoming Supreme Court decision on validity of AEC approval of Fermi site. Nuclear industry is in suspense awaiting decision

Likewise, Southern California Edison said it was "still hopeful of negotiating the site at Camp Pendleton for our 360-Mwe plant."

Said a Boston executive, "New England Electric System announced some years ago [NU, Dec. '56, R3] that it was planning to build a large nuclear power plant for completion in the mid-60's. There has been no change in this thinking." However officials of the company said it was conducting no active planning or work on the second project yet.

10. With AEC proposing no new civilian reactor starts for the second year running, how serious do you think is the outlook for the U. S. nuclear power program? When do you expect to see an upturn? What do you think is required to trigger it?

Sober, guarded optimism outweighed pessimism by about three to one. Enthusiastic optimism was completely missing—hardly surprisingly. Some examples of the flavor of comments on how the ultimate customer for nuclear power feels about it today:

"Do not think outlook for U. S. nuclear program is serious. Such a gigantic, complex development takes time, and is not to be accomplished properly overnight."

"To us, the 'no new starts' is not important. The real key to economic nuclear power is the development of adequate low-cost fuel cycles. That work is going ahead in some areas, and lagging in others. Such developments in fuel as are achieved can be tested and demonstrated in present reactors and those under construction."

"Perhaps there haven't been new starts, but not because the utilities aren't trying. There is a lot of negotiating going on. . . . There is a lot of research going on . . . When people piece these activities together, there will be a substantial upturn in nuclear generation activity . . . We are substantially optimistic."

"Most significant element today is the accumulation of operating experience on those plants that are now under construction and those whose operations have only recently started. When the industry has had an opportunity to review the experience, they can then consider the construction of a second generation of plants."

"The nuclear power development program in the U. S. has been orderly. Adequate progress is being made. Economic nuclear power will be available when it is needed, where it is needed, throughout the U. S."

"Forecasts on nuclear power cost haven't been too far out of line, but forecasts on fossil fuel were so completely wrong they have gone down instead of up. Nuclear is right on the borderline of breaking through, being justified economically. What is needed to trigger upturn is an increase in the price of coal and oil!"

"We think the U. S. nuclear power program is in pretty good shape."

On the other side of the coin:

"The outlook for nuclear power isn't bright. I think any upturn is going to depend on Federal government participation. The government itself might even have to build some of the prototype plants because no one else seems to be rushing to do it."

"As a general rule, the industry feels that the present world abundance of fossil fuels leaves not much incentive for nuclear power production. It seems that it would take a shortage of fossil fuels to trigger an upturn in nuclear power, and we have no way to predict when that might be."

"The present outlook for the total nuclear power program is not one of optimism. A reversal of this trend will be accomplished when the three parties involved (government, industry, utilities) begin working together toward one common goal: a safe low-cost method of producing electricity" from nuclear energy.

No Early Change Foreseen in Washington Reactor Policy

No sweeping changes are in sight for the Civilian Reactor Development Program, at least in the first year of the Kennedy Administration. This is the outlook after the "first 100 days" of the new Administration.

For public power groups, labor unions and reactor manufacturers, heretofore hopeful that the Democratic President Kennedy and a new AEC Chairman (Glenn T. Seaborg) would bring with them assurances of a faster move toward economic nuclear power, the news is hardly consoling.

Their fear is that unless high-level policy decisions are made immediately to mark out basic technology and economic power objectives, AEC's Civilian Reactor Program (against a current background of plentiful fossil fuels) may run out of steam within 2–3 years.

So far White House thinking has not advanced to a solid position one way or the other on the importance of federal support for a major nuclear electricity generation program. This situation leaves the immediate shot-calling squarely where it traditionally has been, in the hands of AEC and the Joint Committee on Atomic Energy (*see editorial page 136*).

The attitude of AEC and JCAE decrees no new or dramatic unveiling of another national policy statement for accelerating current programs. But their present efforts show that some things are being done to, at the least, keep the program moving and even accelerate it a little—in the areas of both program direction by the Division of Reactor Development and in the authorization of reactor construction projects by JCAE for fiscal year 1962.

AEC Review, Reorganization

AEC indicated at Congressional hearings earlier this year a certain amount of displeasure with the existing Cooperative Power Demonstration Reactor Program, particularly "the reluctance of most utilities to accept the financial burden" of second and third round ground rules. Commissioner Robert S. Wilson has taken primary responsibility for the Commission in reviewing the Cooperative Program to determine modifications for strengthening future partnership round projects, while Chairman Glenn T. Seaborg familiarizes himself with specific objectives of the over-all civilian reactor program.

Seaborg has given his endorsement to continued participation by both public and private utilities in any federal outlay for power reactor construction. Meanwhile, he is starting visits to reactor field installations preparatory to calling the Commission together to identify and consolidate power reactor goals. The Wilson review thus far has found:

- Lack of evidence to alter significantly conclusions and recommendations of the 10-year development program, or to change its status as the basic technical guidance document.
- Implementation of the 10-year program will continue under some type of partnership ground rules with utilities, rather than by federal construction of prototypes exclusively.
- The domestic civilian power program is at a point where the fruits of several years of labor are about to be gained, from start-up and near start-up of a number of projects. Consequently, no fundamental changes in present ground rules should be recommended which would disturb the advantages of this position.

AEC's Reactor Development div., meanwhile, is studying the possibility of expanding its civilian reactor staff, which is thought undermanned in comparison to military reactor sections. No specific proposal has been made to the Commission as yet, however. The American Public Power Assn. has recommended establishment of a separate Civilian Power Reactor Development Div. which would be concerned exclusively with pressing power reactor development.

Also, Reactor Development Chief Frank Pittman has been considering the creation of two new civilian reactor posts in DRD: one for conceiving and encouraging demonstration reactor projects; the other to see that they are carried through construction after AEC and Congressional approval.

Congressional Attitude

Chairman Chet Holifield (D-Calif.), assuming leadership of JCAE just as the Kennedy Administration begins to pick up speed, also is recommending no substantial departure this year. A minor modification of present procedures, under which non-water reactor prototypes would be AEC-financed, may be advisable, according to Holifield.

He is satisfied that the AEC fiscal 1962 construction budget—rounded out by Kennedy's recent $93.8-million additions (*see page 21*)—constitutes a "creditable program."

Holifield denies that there will be re-introduction of Gore-Holifield-type legislation for an accelerated federal reactor prototype construction program. There have been persistent rumors, however, that a labor-public power campaign is seeking White House support for reviving the 1956 bill, which was narrowly defeated in the House.

Excellent rapport exists between the White House and Holifield who also acts as chairman of the House Study Group. This is an 80-odd member bloc of liberal Democrats who have banded to help pass legislation proposed by the President. Holifield, therefore, holds an opportune position for assessing priorities for nuclear construction projects with Pres. Kennedy and to gain consent for his proposals from both the Executive Branch and Congress.

However, Jerome B. Wiesner, Kennedy's science adviser, is considered a formidable rival to Holifield on nuclear policy decisions reached at the White House. Wiesner, according to some in Washington, had considerable influence in the decision to kill the nuclear airplane (*page 22*).

AEC studying new reactor use; Page leaves Army program

Selected companies were asked by AEC to propose Apr. 17 on a new idea for military nuclear power. AEC wants a 4–6 months' study conducted on the mating of mobile nuclear power (as an "energy depot") with new direct-conversion systems which might feasibly be employed in vehicles and other equipment. Thus the contractor to be selected would report back on both the best prospective reactor system and the systems which might best use the reactor power—either directly or in stored form.

Meanwhile, Col. W. C. Gribble is expected to assume direction of the Army Nuclear Power Program July 1, succeeding Col. G. B. Page, who has left for an Engineer Corps post in Dallas. Lt. Col. Henry C. Schrader is acting director until Gribble takes over and Melvin A. Rosen, a former branch chief, has been named deputy director of the program at AEC—the first civilian to hold this post.

ANP Killed; Hanford and Stanford Funds in Amended Budget

The on-again, off-again Aircraft Nuclear Propulsion program came to the end of the road last month, dropped entirely from President Kennedy's amended fiscal-'62 budget. Included in the new budget are funds for conversion of the Hanford New Production Reactor to dual-purpose, and for construction of the two-mile-long Stanford accelerator.

All that remains of ANP, a $150-million/yr program in recent years, is a $25-million item in the amended fiscal-'62 budget for high-temperature high-performance reactor research, some of it at existing ANP plants, though not for ANP itself.

Left over in the wake of a 15-year, $1-billion effort, are vast and far-flung special-purpose facilities and laboratories valued at about $175.2-million. Eliminated are some 7,028 jobs in seven states—2,755 working for Air Force contractors, 4,183 for AEC contractors, and 90 AEC employees. Breakdowns: Evendale, Ohio (General Electric), 3,552 (1,580 on AF contract, 1,900 on AEC contract, 72 AEC); National Reactor Testing Station, Idaho (General Electric), 511 (105 on AF contract, 400 on AEC contract, 6 AEC); Middletown, Conn. (Pratt & Whitney), 2,480 (735 on AF contract, 1,733 on AEC contract, 12 AEC); West Palm Beach, Fla. 40 on AF contract; Fort Worth, Texas (Convair division, General Dynamics), 240 on AF contract; Dawsonville, Ga. (Lockheed Aircraft), 55 on AF contract; Oak Ridge National Laboratory, 150 on AEC contract.

AEC sent cancellation telegrams to both GE and P&W directing the contractors to discontinue all ANP work.

Rep. Melvin Price (D-Ill), stunned at President Kennedy's cancellation of ANP only a few days after a meeting with the President had given no warning of such drastic action to come, said he still believes Russia will soon fly a nuclear plane. On that day, he predicted, "the same people who advised termination of the ANP program will turn around and recommend startup of a crash program." Price, long-time defender and principal champion of ANP, blamed the continued opposition and prevailing philosophy of former Director of Defense Research & Engineering Herbert York and of the Air Force Scientific Advisory Board as being primarily responsible for killing ANP. He said the Joint Committee on Atomic Energy would continue to keep a close watch and to conduct periodic hearings, looking toward the time when a flight program once again could be revived and effectively pressed.

Gen. Irving F. Branch, head of ANP for both AEC and the Defense Dept., said regretfully that 1960 was the only year in which the program ran in one direction for an entire year and with a really strong effort, working with hardware. He repeated his prediction of last summer (NU, Sept. '60, 25), stating that both the direct-cycle and indirect-cycle nuclear engines would have been able to fly a plane in 1965.

"We have no sour grapes, no bitterness," he said. "If the boss says kill it, we kill it—our job is not to find ways of reviving it. Only I have a firm conviction that this thing is useful and that some day we will have to come back to nuclear flight."

Convert ANP for Land Power?

Construction of an experimental power reactor using aircraft reactor technology is now being considered at AEC. Such a unit would probably be an indirect-cycle unit, as "the one from which more valuable information might be claimed." The reactor, at an estimated cost of $18–20-million, would probably be built by Pratt & Whitney, developer of the indirect-cycle approach in ANP. Such a reactor would probably be molten lithium cooled, with a primary circuit made entirely of niobium to contain the lithium.

Amended Budget Up $30.1-Million; 2d Antarctic Reactor Asked; Funds Increased for Rover, SNAP, Naval Program

President Kennedy's amendments to AEC's operating and construction expenses for fiscal 1962 appear headed for successful passage by Congress in the coming legislative action on the federal budget. The President's proposed $30.1-million increase—lifting the AEC budget from the Eisenhower recommendation of $2,598,050,000 to $2,628,150,000—substantially meets requirements for a "creditable program" specified by Chairman Chet Holifield (D-Calif.) of the Joint Committee on Atomic Energy.

Holifield had said Hanford NPR generating equipment (*see p. 23*), the Stanford 10- to 20-billion electron volt linear accelerator, and several past-year reactor authorizations on which construction had not started, should be included in AEC's building program. The President recommended all items in the Holifield list and added $7-million for a second Antarctic reactor at Byrd station for good measure.

Estimated cost of the Hanford powerplant is $95-million (not, of course, included is the $145-million cost of the reactor). The Kennedy amendments ask for $60- of the $95-million of this amount to get work started on converting the plutonium production reactor to dual-purpose electricity generation on July 1. AEC estimates total Stanford costs at $107-million, of which the administration is requesting $26-million in fiscal 1962.

Included in the amended budget is a request for 10 additional Polaris-firing submarines and for a construction speedup in those already ordered (*see p. 25*).

Whether the Joint Committee will write into AEC construction authorizations a second reactor project for a remote military site reactor—possibly at Guam—is debatable in view of the healthy $93.8-million total increase already asked by Kennedy for the nuclear construction program. There was no AEC request for the Guam reactor in its budget studies preparatory to the recent Presidential amendments.

The boost in the construction portion of AEC's total budget raises the January (Eisenhower budget) figure of $174.95-million to $268.75-million, an increase of $93.8-million. Other projects benefiting include Project Rover (nuclear rocket), $5-million for additional test facilities; Oak Ridge Experimental Gas Cooled Reactor, $6-million; BORE (Beryllium Oxide Reactor Experiment, first reactor step in developing a Maritime Gas-Cooled Reactor), $8-million.

Operating expenses of $2,423-million in January were decreased in the Kennedy budget by $63.7-million. Of the latter figure, termination of the ANP program accounts for $35-million. Fissionable material production and weapons fabrication decreased by $32-million, and carryover funds of previous year projects (accruing largely from contract renegotiation savings) resulted in a further $26.7-million reduction. Offsetting in part these operating decreases are increases in other areas of reactor development ($3.5-million more for naval reactors, $6.5-million more for SNAP, $5-million more for Rover operations, etc.) and $7.73-million more for physical and life sciences research including oceanography.

The total $63.7-million operating decrease subtracted from the $93.8-million construction increase netted the $30.1-million over-all budget addition.

White House Reviews Nuclear Rocket; 7 Engine Bids Filed

The nuclear-rocket program passed under what could become a dark cloud last month when the White House confirmed that an ad hoc committee was reviewing the program for Jerome Wiesner, scientific adviser to President John F. Kennedy. The review may or may not result in a favorable report on the urgency of the nuclear-rocket effort: but the mere fact of the review, coming just as the review-riddled nuclear airplane was being shot down (*page 21*), lent a definite note of apprehension to it.

For one thing, it was the first major review of the nuclear-rocket program by an outside group, thus ending a period of "freedom from review" of this project; for another, there was fear that even a generally favorable report might call for a change of direction that would get the present program, which is approaching engine development (*see below*), off course; and, finally, the review is a broad one covering the basic role of nuclear rocketry in the future U. S. space effort and any adverse report at this point could have a long-range effect on the development program.

Nevertheless, most government and industry observers of the review felt the review committee would recognize that the nuclear rocket was urgent. They noted that Wiesner, in selecting the review group, had said he was trying to be open-minded and had tried to organize the committee with about equal numbers of neutrals and those for and against. The members: Harvey Brooks of Harvard, chairman; Walter Zinn, Combustion Engineering; Stanislaus Ulam, Los Alamos Scientific Laboratory; Arthur Biehl of Mainhard-Biehl Associates; Theodore Merkle of Lawrence Radiation Laboratory, Livermore; Allen Donovan of Aerospace Corp.; Berndt Matthias of Bell Laboratories; Eugene Wigner of Princeton; and William Graham of Rand Corp. Secretary to the committee—strictly an ad hoc group—was Spurgeon Keeney of the White House staff.

Sen. Clinton P. Anderson (D-N.M.), who has had a series of meetings with Wiesner in an attempt to head-off action detrimental to the nuclear-rocket, said he was satisfied that the Brooks Committee would conduct a fair review. Meanwhile, JCAE has brought in Clark Goodman, formerly of AEC's Reactor Development div., as its own one-man review committee.

Seven Nerva Proposals

Meanwhile, seven firms or groups proposed to AEC/NASA's Nuclear Propulsion Office (NPO) on a first-phase contract expected to lead to development of a nuclear-rocket engine (Project Nerva). Proposals were filed Apr. 3 by: Aerojet General Corp., teamed with AMF Atomics (assembly, disassembly, etc.) and Bendix Aviation (control-rod actuators); American Metal Products Corp., Ann Arbor, Mich.; General Electric (GE has a nuclear rocket task force coordinating the activities of two rocket groups—one within the Aircraft Nuclear Propulsion dept., the other in the Flight Propulsion dept.); Pratt & Whitney; Rocketdyne div. of North American Aviation, with its sister division Atomics International (reactor) and ACF Industries, Albuquerque, N. M. (assembly, disassembly, etc.); Thiokol Chemical Corp., as prime for the Talant group (Allison div. of General Motors, Linde div. of Union Carbide, and NDA div. of United Nuclear Corp.); and Westinghouse Astronuclear Lab, with Bell Aerospace Systems doing some engine work.

There were indications that NPO was leaving itself free to select given members of proposing teams, rather than an entire team or a single company proposal, and that the overall goal was to get an engine contractor or team into the program by early this summer. The initial contract is to cover no more than a year and include preliminary engine design, study of an engine-development program, certain development tasks on non-nuclear components and support of Los Alamos in the Kiwi-B series.

LASL officials, extremely optimistic about their progress in reactor development to date, will run one more gaseous-hydrogen experiment this fall at Jackass Flats, Nev. If this is successful, a series of liquid-H experiments will get underway early in 1962; a total of 4–5 experiments, or as many or more than will have been conducted through 1961, are to be run during 1962. LASL hopes that midway through this series—or after two liquid-H runs—it will have a reactor it can hand over to an engine contractor. If so, it appears likely that a nuclear rocket could be available for flight-test by 1965–66, providing adequate development funds are available. A LASL official summed up the reactor-development program this way last month:

"We think we have made very good progress. But that doesn't mean we haven't got problems. . . . We haven't touched liquid hydrogen. . . . It all depends on one's degree of optimism as to how the [coming] tests will go. . . . I think there's a legitimate reason for trying to speed up nuclear rockets. That is: If they are successful, they may save time and money that you would have had to spend if you had to develop chemical rockets to do the job nuclear rockets would do.

"From that standpoint, I don't think there's anything bad about bringing in an engine contractor, no matter what shape you're in."

Marshall Supporting Nuclear Vehicle Studies

NASA's Marshall Flight Center, Huntsville, Ala., has recently received proposals from industry for studies of three rocket configurations using nuclear powered vehicles. The configurations, all tentative because nuclear-engine technology is just in its infancy, are known as Saturn D-1, D-2 and D-3. Saturns D-1 and D-2 would use nuclear rockets of different power levels as third stage vehicles; Saturn D-3 would use nuclear vehicles as both second and third stages. Power levels for the nuclear vehicles, also tentative, would begin at 1,000 Mwe for Saturn D-1 and go up from there to D-3. Presumably, the studies, on which airframe companies are bidding, would involve integration of these nuclear rockets with Saturn first and second stages. Saturn is scheduled to be operational in 1964 and target for flight-test of nuclear rockets riding on Saturn boosters is 1966–67 (story this page).

In mid-March, Marshall, which is to manage flight-testing of Saturn/nuclear-rocket complexes for NASA, announced the award of three contracts for broader studies involving nuclear vehicles. The studies are to cover about a dozen Saturn configurations involving liquid chemical fuels, solid fuels, and nuclear fuels; both upper stage and booster nuclear vehicles are to be included. NASA said the study considerations included: optimum use of nuclear propulsion in large rockets; combination of liquid chemical and nuclear propulsion; desirability of attempting to recover and re-use boosters; conventional tandem staging versus parallel staging; and pressure-fed versus pump-fed booster systems.

The contracts went to Convair div. of General Dynamics Corp., $130,017; Lockheed Aircraft's Georgia div., $136,743; and North American Aviation, $160,041. The studies are to be completed in August.

FPC Study Backs Administration Decision to Convert NPR to Dual Output of Electricity, Pu: 650–753 Mwe Expected

Convertibility of the Hanford New Production Reactor (NPR) to a dual-purpose plutonium and electricity generation facility is still valid and economically feasible, according to an updating study by the Federal Power Commission.

The updated estimate is contained in a background report released by the Joint Committee on Atomic Energy last month. JCAE's background report contains five other past feasibility studies on NPR convertibility-to-power economics. The report will be used in coming Congressional action to support construction of the generating facilities, recommended by President Kennedy's recent amendments to the AEC budget for 1962 (*see page 21*).

FPC's latest judgment of feasibility estimates that the $95-million cost of the electric plant plus all operating costs will not exceed the value of the power which will be produced. It also means that the government believes there will be a market for the NPR power, and that its costs of generation will not exceed the costs of power from alternate fossil fuel-fired and hydroelectric plants in the Pacific Northwest power area.

FPC stuck by some contingencies included in its first report, however. Its latest findings thus are that NPR nuclear power will be no more costly than conventional fossil fuel or hydro power if plutonium continues to be needed and its price remains stable. (A disarmament agreement could effectively cancel major Pu requirements.) Total costs of operating the NPR are classified to protect U. S. Pu production figures. They appear in a secret volume appended to the FPC study. Should forecasts of long term northwest power area requirements, felt by FPC to be reasonable possibilities, fail to measure up, the value of NPR power would decrease.

Costs of Electricity

At-site values placed on Hanford power based on steam-electric alternate sources over a 33-year plant life were $12.06 per kilowatt-year for capacity and 2.35 mills/kwh and $20.50/kwyr for energy for the first eight years of dual purpose operation. For remaining years of power production only, a capacity value of $9.60/kwyr and energy values of 2.87 mills/kwh and $25.14/kwyr were estimated.

Hooking on power-production generators now costs $17-million less (a change from $104-million to $87-million) than FPC estimated last year. The reduction is due to information from turbine generator makers that the 786-Mwe generating capacity can now be delivered by two 393 megawatt units instead of the three units earlier thought necessary.

The plant factor of NPR changed in the FPC updating report. The plant factor during the 1964–72 dual purpose period was dropped from 40% computed last year to 30%. The estimated decrease in energy that NPR is required to furnish through the Bonneville Power Administration grid in its first few years is due to increased storage of water for the Columbia River basin as a result of the U. S.-Canada Treaty. Load estimates also decrease for the area in this period. This means the NPR energy at a 30% plant factor in this time will cost more than alternate steam-electric power.

A greater degree of economic feasibility for making NPR a power production facility, however, is the effect of over-all changes since last year's study by the Power body.

It was also concluded that the most economic reactor would be one of 650 Mw(e) capacity during the 1964–72 dual-purpose period of operation, and 763 Mw(e) capacity in the 1972–97 power-only period. All 22 reactor schematic arrangements investigated by Burns and Roe, architect-engineer consultant to the FPC study, with electrical capacity ranging from 271 to 842 megawatts, assumed a reactor life of 35 years.

The separate $145-million reactor construction authorized by Congress in 1958 is proceeding under Kaiser Engineers and General Electric. The reactor is due to start up in October, 1962. A two-year "debugging" and initial plutonium only production period is scheduled to show reliable continuous operation of the reactor. This is required for the generation of electrical energy, and would allow plutonium-electricity dual operation beginning in October, 1964.

Secretary of the Interior Stewart Udall and Bonneville Power Administrator Charles Luce have given their strong endorsement to the NPR power-conversion project.

AEC moving toward clean-up program for SL-1

AEC has begun exploring, with operating contractors and at least one private firm, the possibility of "cleaning up" and dismantling for study the core of SL-1, which has been sitting silently at the National Reactor Testing Station since the accident of January 3 (NU, Feb. '16, 17). AEC officials said last month it was not likely that Combustion Engineering would direct clean up of SL-1 because of AEC's feeling that CE, as operator of SL-1 and the company carrying out inspection of the reactor since the accident, should give way to a disinterested party. Idaho Operations Office of AEC was exploring clean-up possibilities with Sandia Corp. and other candidates among AEC's operating contractors and with Hughes Aircraft Corp., which has asked to do the job with its Mobot remote-handling equipment.

Meanwhile, AEC said that it had gone into the SL-1 tank in March with a blotter probe and found no water at the top of the core. Pending deeper probing, AEC was theorizing that the core was probably dry and that "dismantling could probably proceed without introducing water [with boric acid] into the core." Clean-up and dismantling procedures were not expected to be settled finally until an ad hoc committee on SL-1's future use and disposition could review the situation and make some recommendations to the Commission. The committee is headed by Frank Pittman, director of AEC's Reactor Development div.

Late last month, AEC was trying to get deep into the SL-1 tank with a flexible probe designed to establish the depth of water in the tank, if any. The probe consisted of 41 plastic spools on a flexible line; the porous spools carried potassium-permanganate crystals, which turn purple on exposure to water. Each spool was 1 in. long, by ¼ in. in dia. The probing crew was having trouble getting the line down into the core because of obstructions but was experimenting with television cameras positioned to permit jockeying of the line.

AEC Nearing Steps to Increase Industry Role in Program

In January a year ago the then chairman of the AEC, John A. McCone, invited the U. S. Chamber of Commerce to form a study group on the role of private industry in the nuclear-energy program—with particular attention to the question of industry's getting a larger share of the work performed in AEC-owned facilities.

Last month, after months of quiet negotiation with AEC, the Chamber's Task Force on Increasing the Role of Private Industry in the Government's Atomic Energy Program reported its first signs of progress. They were:

- The likelihood that AEC would accept the Task Force's suggestion for creation of an office or division within AEC on commercial activities. No formal AEC action had been taken as of mid-March but AEC officials indicated that formation of a commercial-activities group could be expected this spring.
- Probable establishment of a reporting system, under which government-owned facilities would report to Washington on work they are scheduling and the extent to which they considered assigning it to private industry before deciding to do it "in-house." The Chamber suggested that such a reporting system be set up by the proposed commercial-activities group.

Industry observers of the Chamber-AEC negotiations have been quick to point out that the proposed commercial-activities group must be given division-level authority—under a man of stature—if it is to perform an effective job. AEC has had two previous offices of this type—one in the early 1950's and the other three years ago—but neither was a particularly influential force within AEC. Moreover, the current "recession" in the nuclear-power business has given more urgency than ever to activities which lead to assignment of more AEC work to industry.

The Background

The Chamber Task Force was created in the spring of 1959 under the chairmanship of Philip N. Powers of Purdue Univ. and formerly of Internuclear Corp. (NU, May '60, 29). Late in the year, after both formal and informal contacts with AEC officials (principally Commissioners Robert Wilson and Loren Olson), the Task Force submitted a proposed report to McCone. Among other recommendations, the Task Force suggested:

"We invite the Commission's consideration to the possible re-establishment of the Office of Commercial Activities. This would provide a staff with adequate status to fully investigate this problem [of increasing industry's role] and to find the best ways for the AEC to carry out its responsibilities in relation to the 'free enterprise' objectives of the [1954 Atomic Energy] Act. We believe this work should be at this high level within the AEC staff, because the development of commercial activities affects the program of all of the operating divisions of AEC.

"We believe that AEC should be receiving regular reports from its field offices on work they are considering doing in government-owned facilities. These reports should include, for each job that exceeds a certain dollar value, the following information: a brief description of the job; an estimated dollar cost of doing the job; what was done to determine industry's interest and capability to do the job; why consideration is being given to doing the job in government-owned facilities."

Acting Chairman John Graham replied for AEC on Jan. 27, a week after McCone left office. Graham's reply was both sympathetic and unusually frank. "I am sure you realize," he told the Chamber, "that under the Atomic Energy Act the Commission's primary objectives must be the development and production of weapons and the conservation of dollars." The "conservation of dollars" objective has been a particularly crucial factor in some AEC decisions on whether to assign work to industry. Graham continued: "Of course, this does not mean that the Commission is not strongly interested in implementing the free-enterprise policies of the Federal Government in every way possible." He said both the commercial-activities and reporting-system suggestions of the Task Force had "merit" and were being seriously studied by AEC.

AEC Contractors

Graham also commented: "I might mention that I think the Chamber has a problem with industry itself, mainly as large companies operate our large government-owned installations. The attitude of our cost-plus-a-fixed-fee contractors, who perform much of the procurement for the Commission, does affect the extent to which other private industry can have the opportunity to do some of the work. In other words, you might examine to what extent a large company operating an AEC-owned facility can foster work to be done by private industry, other than in the AEC-owned facility."

The Task Force, recognizing that it must deal with AEC's operating contractors, as well as AEC itself, was turning its attention to this area of competition. The group intends to continue its contacts with AEC on the proposals now pending but to give particular emphasis to the operating-contractor "attitude" noted by Graham.

Inter-Industry Committee on Competition Organized

Four associations representing private industry, including the U. S. Chamber of Commerce (see story this page), have completed organization of the Inter-Industry Advisory Committee on Government Competition to coordinate and supplement the efforts of each of the four member groups in reducing government competition in the nuclear field. The other members: National Assn. of Manufacturers, Edison Electric Institute and Manufacturing Chemists Assn.

Representing each of these groups on the Inter-Industry Committee are: NAM, George W. Wunder of National Lead Co., Lauchlin M. Currie of Babcock & Wilcox and Bruce S. Old of Arthur D. Little, Inc.; EEI, Edwin C. Vennard and John J. Kearney, both EEI officials; MCA, C. D. Harrington of United Nuclear Corp. (NU Apr '61, 21) and T. C. Runion of Davison Chemicals Div., W. R. Grace & Co.; and USCC, Arthur V. Peterson of his own firm and Philip N. Powers of Purdue Univ. Currie has been acting as chairman of the Committee, which is not expected to get active until a permanent chairman is named.

The Committee's objectives include: pooling information on programs being undertaken by each group in "current and potential areas of competition in the nuclear field"; coordinating and supporting activities of individual organizations; and undertaking projects of mutual interest. "In the long range," says a Committee statement, "economic development of nuclear energy will be accomplished by industry. However, situations have arisen within the past six years in which there is direct competition between private nuclear industry and government-owned facilities. Efforts to minimize such competition between the Government and industrial concerns should be undertaken now before the problem becomes more serious."

REACTOR NEWS

PG&E DEFERS BIG PLANT DECISION

Pacific Gas & Electric Co. is still "a couple of months away" from a decision on whether to build its contemplated 300-Mwe reactor in the San Francisco area, probably at Bodega Head. "We are still about at the same place as we were in January," President Norman R. Sutherland said. "Some other urgent things came up and we put it aside for a while, but not for long. In a couple of months we'll get around to it again and then we'll give it further study."

McMURDO REACTOR WELL UNDER WAY

Site preparation has been completed on a low hilltop overlooking the Navy's Ross Island base on the shore of McMurdo Sound; actually, foundations were dug not for one but for two reactors side by side, although only one has been authorized so far. Housings for the primary and secondary circuits have already been delivered. The Navy Antarctic Projects Office has set the following schedule: assembly primary plant foundation, Oct. 1–15, 1961; assembly secondary plant foundation, Oct. 15–30; erect primary plant superstructure and building shell, Oct. 15–Dec. 15; erect secondary building, Nov. 1–Dec. 15; assemble nuclear power plant, Dec. 15–Feb. 28, 1962; install and connect substation and pole line to existing electrical distribution system, Oct. 15–Feb. 28; nuclear power plant on line March 1, 1962.

ML-1 GOES CRITICAL

The Army's Mobile Low-power reactor No. 1 went critical on schedule March 30 at the Idaho test station. The 3.4-Mwth, 0.3–0.5-Mwe truck-mounted reactor, built by Aerojet-General Nucleonics, will undergo low-power testing this summer, will be joined in October to its closed-cycle gas turbine and generator unit (NU, April '61, 29), and is to reach full power about Nov. 15.

DRESDEN: POISON BLADES ALSO IN TROUBLE

Dresden Station's materials problems with cracking in 17-4-PH steel, as a result of which all control-rod drive parts of that material are being replaced (NU, Feb. '61, 25), have extended to the control blades themselves. Cracks were found in a number of the poison sections, made of 2% boron alloyed in stainless steel. General Electric, builder of the Dresden reactor, is replacing all the control blades with ones of a new design developed for the Big Rock Point reactor: 10 slender tubes of 304-type stainless steel packed with compacted boron carbide and sealed at both ends are fastened between two sheets of stainless steel in such manner that the total thickness of the sandwich is small enough to slide up and down in the existing control-blade channels; four such sandwiches will be fastened to form one cruciform control rod—40 tubes of boron carbide per rod. GE has promised to have all 80 replacement rods delivered by April 8. A hearing March 28 covering Dresden modifications was adjourned to April 10 to get a report on the new rods.

SKATE SETS CORE MARK; POLARIS SPEEDUP

The submarine *Skate* sailed a record 120,862 miles on her first core, and is now being refueled—after 39 months' service—at Electric Boat's Groton, Conn., yards where she was built. The distance compares with 69,138 miles in 26 months by *Nautilus* on her first core; 93,000 miles in 26 months by *Nautilus* on her second core; and 71,609 miles in 23 months by *Seawolf* on her first, sodium-cooled, core. These are the only nuclear submarine refuelings to date. The dramatic improvement in core-life shows the strides being made toward the goal of developing a core that will last the life of a ship. . . . President Kennedy's speedup order for the Polaris program has manifested itself 1. in award of five *Lafayette* (third-generation) Polaris hull orders for which long-lead-time reactor parts were authorized last year—two to Electric Boat, two to Newport News Shipbuilding & Dry Dock Co., one to Mare Island Naval Shipyard; and 2. for fiscal-'62, Kennedy asked for 10 new Polaris subs, to make a total of 29, plus a (third) Polaris tender. He also asked for an accelerated construction schedule, under which the 10 FY-61 and 10 FY-62 Polaris subs would be delivered beginning June 1963 at a rate of 12/yr as against the present rate of 5/yr. This would cut two years off the completion schedule for the first 29 Polaris craft. The Navy wants a fleet of 45.

BNL REACTOR SAFETY PROCEDURES HIT

AEC last month ordered shutdown of Brookhaven's reactors and critical assemblies pending changes in operating and maintenance procedures that were considered unacceptable. The changes were instituted in time to prevent any interference with the reactors' regular schedules. The steps were ordered by AEC reactor development chief Frank K. Pittman, reacting to BNL's reply to the survey of reactor safety practices instituted by AEC following the SL-1 accident. Pittman told NUCLEONICS there was "a complete difference of opinion" between his and Brookhaven's philosophy on reactor operation: BNL believes in recruiting technically competent people, giving them responsibility, then letting them operate, whereas Pittman feels while it is necessary to have competent people and give them responsibility but also to put limitations on what the operator can do and provide for compulsory formal and independent review of what he does. Pittman said the BNL safety survey reply made him feel that its procedures "were not detailed enough, or didn't exist, or were not updated, or did not provide for review by Brookhaven's safety committee, or did not take abnormalities into account." Henceforth Brookhaven's safety committee will have to review all procedures and changes on a formal basis, rather than merely being available to give assistance if the operator felt he required it. All restrictions have now been lifted from the Brookhaven reactors, and the special committee Pittman sent to investigate the situation has now been discharged. The reactors are back in operation, except the medical reactor on which modifications were being completed as this went to press.

NUMEC STARTS Pu, Hf PLANTS

NUMEC placed two plants on stream within two weeks. One, producing hafnium crystal bars from sponge, will supply the material for control rods for naval reactors under a $500,000 contract. The other, first fully-integrated commercial plutonium facility, will make plutonium-beryllium sources (first orders have already been received, from civilian and military customers in the U. S. and abroad), as well as carry on research-development work on Pu and plutonium oxide fuels for power reactors . . . NUMEC also claimed a major breakthrough in application of beryllium oxide protective coatings to uranium dioxide in "fairly thick" layers, up to 100 microns. The same process—which NUMEC did not reveal—works sucessfully also with zirconium oxide, molybdenum, niobium, vanadium chromium, aluminum oxide, pyrolytic graphite, beryllium, tungsten, etc.

WORLD NEWS

AI Signs for AKS Organic Design

Atomics International has signed a long-expected contract in West Germany for design of a 150-Mwe organic reactor for AKS's successor group, the 13-utility KBWP (Baden-Württemberg Nuclear Power Plant Planning Assn.). AKS had only been a study group for review of the proposals (NU, Feb. '60, 23; March '60, 27); much of the delay since a year ago was caused by the need for the member utilities of AKS to organize contractual relationships covering share of participation, responsibility, liability, etc. KBWP is a body that could go on to build and operate a commercial nuclear power plant. The Title I design it has ordered so far is to be completed in 13 months; Brown Boveri of Mannheim will design the conventional end of the plant.

A-Tanker: 'In' in Italy, 'Out' in Britain

The cause of the nuclear-propelled tankship moved a long step forward in Italy, backward in Britain. A government-industry project went to design contract stage when the Fiat-Ansaldo study team (NU, July '58, 26) signed on March 17 with CNEN (National Commission for Nuclear Energy) for a two-year joint research program including design of the tanker. Almost half—46% —of the $3.2-million contract cost will be financed by Euratom. The 52,000-ton ship would be 817 ft long, 37.6-ft in draft; its 74-Mwth pressurized water power plant would put out 23,100 hp to drive it at 17 knots. Ansaldo will design the ship, Fiat the reactor. Euratom recently also helped finance the design contract let by Germany's GKSS group to Interatom on an organic-moderated tanker reactor (NU, March '61, 32).

Meanwhile in Britain, expectation was that the nuclear tanker program would be dropped, replaced by a small-reactor program instead. The Admiralty's (Galbraith) Committee on Application of Nuclear Power to Marine Purposes, which two years ago undertook a study of seven proposals for a reactor to propel a 65,000-ton tanker (NU, June '59, 25) and which a year ago asked for bids on a boiling-water and an organic reactor, is now understood to have rejected both. As a result, it's considered almost certain that the government will shortly announce a decision to abandon the nuclear tanker. Instead, a broadly-based program for development of small reactors is likely to be launched soon by the new Reactor Group at Winfrith. First prototype selected for construction is expected to be the steam-generating heavy water moderated reactor (SGHW), originally proposed by Vickers Nuclear Engineering Co. for the tanker. SGHW uses light water coolant circulated in pressure tubes through the heavy-water moderator, thus making steam in the core, eliminating heat exchangers, and reducing the amount of heavy water moderator needed.

Second Power Reactors for Brazil, India

A second large power reactor is contemplated in Brazil. Janio Quadros, the new president, has said he wants another big nuclear unit for the semi-arid northeast "bulge" or the Amazon valley. The first, a 150–200-Mwe plant to be placed on the Mambucaba river between Rio de Janeiro and Sao Paulo, is scheduled for 1965 completion; invitations for worldwide proposals were postponed last fall . . . Homi J. Bhabha, India's AEC chairman, says his country can now design and build power reactors up to 25 Mwe without foreign help, using natural uranium fuel, heavy water moderation, organic cooling. Accordingly India has authorized building of a 20-Mwe plant of this type at Trombay as part of the third five-year plan, in addition to the 150-Mwe Tarapore plant on which worldwide proposals are due in August.

Mexico to Buy Research Reactor

The Instituto Politecnico Nacional of Mexico wants to buy an off-the-shelf research reactor, of up to 1 Mwth, to start training technicians for future nuclear power plants. Internuclear Co. of St. Louis, a subsidiary of Petrolite Corp., has been trying to sell the Polytechnic a "tailor-made" research reactor for its specific needs, but sources in Mexico City say the Polytechnic is in a hurry, prefers to buy a standard unit to save time and money. Atomics International has been reported as a possible supplier. Mexico has no reactor as yet; although rich in uranium, it will not need nuclear power for some time as it also has cheap and abundant oil, gas and water power.

Hawker Siddeley Withdraws from Field

Britain's Hawker Siddeley Nuclear Power Co. is pulling out of the nuclear field—as a result, the company said, of the uneconomic trend in the industry. The firm will close down its factory at Slough, Bucks, over the next six months. A research-development team of 35 there had been working on organic-moderated ship reactor studies and on process heat reactor systems. The company had also had some success in offering its Jason research reactor based on the Argonaut design; so far there has been no decision on the future of this project.

Research Reactors: 4 Critical, 1 Ordered

Germany's FR-2, her first major domestically-designed and -built reactor, went critical March 7 at Karlsruhe. It will operate at 12 Mwth following low-power testing. . . . **France's Rachel**, her first fast-neutron critical assembly, went critical March 8 at an unannounced military research center of the Commissariat à l'Energie Atomique. It has a plutonium metal core; although military research will get top priority, Rachel will also be used to help in design of Rapsodie, France's first fast breeder . . . **Britain's Vera** (Versatile Experimental Reactor Assembly), a 100-watt critical facility, was started up for experiments to improve nuclear data and calculating methods for fast critical assemblies . . . **Britain's Nestor** (Neutron Source Thermal Reactor), a 10-kw, modified Jason- or Argonaut-type, was started up at Winfrith; it can drive five subcritical assemblies simultaneously. . . . **Pakistan** has given AMF Atomics an order for a 5 Mwth pool reactor for its planned nuclear research center.

Japanese Jottings

Major construction began April 1 on the 12.5-Mwe demonstration boiling water reactor to be built by General Electric of the U. S. for the Japan Atomic Energy Research Institute at Tokai Mura. Construction had begun last November, also at Tokai, on the 159-Mwe Calder-type gas-cooled reactor being built, by coincidence, by General Electric Co. of Britain (no affiliation). . . . The Japanese Research Reactor No. 2, heretofore confined to 1 kw (NU Wk, 10 Nov. '61, 2), was to reach 1 Mwth full power by mid-month. The CP-5-type unit was built by AMF Atomics . . . Mitsubishi will build Japan's first domestically-designed and -built research reactor, a 30-Mwth unit similar to Triga Mark 2, at a site of its own adjacent to JAERI's Tokai center. . . . A Japanese mission has been touring the U. S. to study possible installation of a high-powered materials testing reactor in Japan.

NEWS IN BRIEF

IRG Project Delayed, More Study Set

Indefinite postponement of the plan to build a privately-owned fuels-reprocessing plant in favor of a further, more detailed study, was decided on by the Industrial Reprocessing Group. The additional study was felt necessary in order to cover shipping problems, licensing, legal and accounting questions, fuel storage, more detailed economics, etc. It will be sponsored by the original members of IRG (Commonwealth Edison, Consolidated Edison, Detroit Edison, Northern States Power and Yankee Atomic), possibly joined by Consumers Power of Michigan and Southern California Edison. Another possible sponsor is Carolina-Virginia Nuclear Power Associates. The study will cost several thousand dollars and will take up to two years. Davison Chemicals div. of W. R. Grace, Inc., will conduct it with three subcontractors: Bechtel Corp., and Weinrich Associates—both participants in last year's study—and Nuclear Utility Services Co.

Nuclear Optimism Expressed at Power Conference

Impressive optimism on the prospects for nuclear power, was heard at the American Power Conference meeting in Chicago in late March. Titus G. LeClair, of General Atomic, predicted that in ten years the unit price of fossil fuels would have risen by 12.9% while nuclear fuel costs would be down by 9.4%. "The downward trend in the cost of nuclear power," LeClair said, "is so pronounced that development and construction of plants should be pushed to achieve the goal of competitive power." LeClair also foresaw that by 1980, 25% of new generating capacity ordered would be nuclear, and that a total of 45,000 Mwe nuclear capacity would have been installed by then.

R. B. Richards, manager of engineering at General Electric's Atomic Power Equipment dept., declared the state of the art had progressed to a point where a 300-Mwe single-cycle plant could be built for $197/kw—a $53/kw reduction from the $250/kw cost that AEC's 1959 study showed for a 300-Mwe dual-cycle boiling water reactor. "On this basis," Richards went on, "a 400-Mwe single-cycle plant can now be built for $183/kw and a 500-Mwe dual-cycle plant for $176/kw."

Price Named First Director of Regulation

In a major internal reorganization, AEC named Harold L. Price acting director of regulation. Price reports directly to the five-man Commission on all regulatory matters, as part of the new set-up separating AEC's regulatory and promotional-operational functions (NU, March '61, 26). Price has been asked to complete a staffing study by about mid-April; meanwhile, he has assumed jurisdiction over the Division of Licensing & Regulation (which he formerly directed), the Division of Compliance, and the Office of Health & Safety. Robert Lowenstein succeeds Price as director (acting) of the Licensing & Regulation div., and General Manager Alvin R. Luedecke continues to manage operational and promotional activities. Luedecke reports directly to the Commissioners. One problem remaining to be solved, however, as the staff study proceeds, is what to do about the post of Assistant General Manager for Regulation & Safety—now held by William F. Finan. No move has yet been made to reconcile the fact that this regulatory post exists under Luedecke, while a new regulatory post has been given to Price. Thus, Price is authorized to "discharge the licensing and other regulatory functions of the Commission, other than those where the final decision rests with the hearing examiner, or the Commission, or which involve the Commission's authority to approve the issuance of regulations."

ACRS Reports to AEC on Five Reactor Projects

The Advisory Committee on Reactor Safeguards gave qualified or partial approval on five reactor projects last month—Dresden, Indian Point, Elk River, Lockheed's research reactor, and the Small Size Pressurized Water Reactor sites. All are dated March 4 except the SSPWR reports which are under four different dates. **1.** On Dresden: ACRS found no hazard in proposed operation at power with experimental and advanced fuel elements provided maximum heat generation is held to half that which would produce burnout; it asked to review proposed design changes in the control rods—now being changed because of cracks (NU Wk, 9 March '61, 4)—before Dresden resumes power operation. **2.** Indian Point: ACRS approved current design work on control rods and drives; it said that reactor design is "such that it could be operated without undue risk." So far ACRS has not looked at staffing, operating procedures, start-up program. **3.** Elk River: Recent changes approved (NU Wk, 16 March '61, 3); 17-4-PH steel to be watched; reactor can be operated without undue risk. **4.** Lockheed Radiation Effects Reactor: "Continued operation at 10 Mwth in its present design form can only be justified for work essential to the national defense. . . . The hazards to the public from operating this reactor at its designed power and in its present unshielded and uncontained condition are greater than those generally acceptable for licensed reactor facilities. Thus there must be compelling reasons for assuming this additional risk." **5.** SSPWR: Ironically, the reports now published tell how ACRS approved the Dairyland site near Genoa, Wis., on July 22, and two alternate Jamestown, N. Y., sites on Nov. 5. SSPWR has been dropped—at least for these sites—for cost reasons (NU Wk, 9 March '61, 3).

Criteria for State Control Gets AEC Approval

AEC approved recently criteria by which it will eventually transfer to eligible state administrations regulatory duties over certain radioactive materials. Nearly two years in preparation—Congress passed the law in 1959—the criteria must be complied with by the states wishing to assume regulatory control. Regulatory authority over radioactive materials will include responsibility for rule-making, licensing, inspection, compliance, enforcement.

AEC Proposes Indemnity Coverage for Fuel Makers

AEC has called for comment by the end of May on its proposal to extend the Price-Anderson indemnity law to AEC licensees who process unirradiated enriched uranium. Reactor fuel processors and fabricators using quantities of material could be required to have financial protection under the Atomic Energy Act. If AEC requires this insurance, then it must also provide public indemnity—up to $500-million per nuclear incident would be available for public liability claims in excess of the amount of insurance required by AEC. Convair div. of General Dynamics Corp., which prepared a study on possible nuclear accidents in processor's plants, reported a low probability of an incident when safety procedures were strictly observed. The Atomic Industrial Forum, in a recent report, recommended that AEC extend financial protection to processors, that a $10-million protection requirement be put into effect three years after AEC decided to extend the indemnity coverage. In the interim, licensees would keep their present coverage but new licensees would need $10-million.

RADIATION NEWS

Baird Brings $1.7-Million Suit Against NI, REAC

In the latest in a series of suits involving the formation of new nuclear-instrument firms by people formerly employed by the suing company, Baird-Atomics has filed a $1,750,000 suit against five former Baird employees who participated in the creation of Nuclear Industries, Inc., Valley Stream, L. I., and Radiation Equipment and Accessories Corp., Lynbrook, L. I. The suit was filed Apr. 5 in the Eastern District Federal Court, Brooklyn. Nuclear Industries (NI) is managed by Jack R. Carlin, president, Richard E. O'Toole, secretary-treasurer, and Louis W. Mead, vice-president; Radiation Equipment and Accessories Corp. (REAC) is managed by Edward J. Kerzner, president, and Jerry Weinstein, vice-president (NU, March '61, 29). Both companies (REAC is a wholly-owned subsidiary of NI) and all five officers were named in the Baird complaint as defendants; answers to the complaint were due 20 days after service on the defendants, according to Baird attorneys (the New York City law firm of Day, Epworth, Plaskow & Lawrence).

The case differs from a simple employer–vs–ex-employees suit in that Carlin, Mead and O'Toole were the founders of three firms purchased entirely by Baird in April, 1959, with the founders going to Baird as officials or employees. They took Baird stock in exchange for the stock in their firms, with some Baird stock going into escrow for delivery in three annual installments provided the sellers were still in Baird's employ. Carlin resigned after disagreements with the Baird management in September last year; the others left Baird later last fall, according to the complaint. The complaint specifically charged that the defendants:

- Allegedly "conspired with each other" during purported meetings prior to Carlin's resignation from Baird, "at which meetings the individual defendants agreed to organize a competing company and subsidiaries in direct competition to the plaintiffs herein."
- That the defendants have allegedly "induced and enticed and still are attempting to induce and entice manufacturers to terminate their franchise arrangements with" Baird and a subsidiary, Atomic Accessories, Inc.
- That the defendants allegedly "caused serious resignations" of Baird employees; "of the 18 men in [the] Baird-Atomic, Inc., sales force as of September 1, 1960, Nuclear Industries, Inc., now has nine men plus one serviceman," according to the complaint.

Baird, NI Participate in Formation of Two Firms

Baird-Atomic and Nuclear Industries, principals in a Federal Court action last month (*see above*), participated in the formation of two radiation companies before Baird filed its suit on Apr. 5:

Transnuclear Corp., Westwood, N. J. Transnuclear was established by Isotopes, Inc.—with NI holding some of Transnuclear's stock—to manufacture nuclear instrumentation. Transnuclear is an Isotopes, Inc., subsidiary located across the street from the parent firm's headquarters in Westwood. The new firm was expected to go into production quickly with a line of low-level beta-counting instruments designed and marketed formerly by Isotopes; pilot runs on other instruments were scheduled for later this year. All of Transnuclear's instruments are to be transistorized and marketed by NI. Three officers of Isotopes, Inc., are serving in the same capacities at Transnuclear until the press of duties requires separate management: Richard D. Janes, president-treasurer; Donald R. Carr, vice-president and assistant secretary; and Robert Kleiner, secretary.

ChemTrac Corp., Cambridge, Mass. This new radiochemicals firm has been founded by Baird and Controls for Radiation, Inc. (Con-Rad), which is making part of its Cambridge headquarters available to ChemTrac. Con-Rad holds a majority interest and Baird will market all ChemTrac products; only carbon-14 compounds were to be marketed initially, with expansion into other compounds as indicated. Irving Berstein, president of Con-Rad, is also president of ChemTrac but he is leaving management of the new company to John Leak, formerly of Isotope Specialties div. of Nuclear Corp. of America.

Former Lockheed Group Creates Instrument Firm

Radiation Technology, Inc., Atlanta, has been established by a group of former Lockheed Aircraft employees, with the help of investment and business interests in the Southeast. RTI will produce fully transistorized instruments—survey meters and scalers initially, to be followed eventually by multi-channel analyzers, a liquid-scintillation counter, a line of monitoring instruments and special-purpose scalers. The company also expects to get into pulse-height analyzers and instrumentation for process-control and outer-space applications. RTI officers: James T. Bracken, president; William R. Champion, secretary; Loyce A. Turner, treasurer; and Stephen Johnson, production manager. Bracken had been manager of the nuclear measurements dept. at Lockheed.

Texas Group Working on Three Radioisotope Projects

A group of Chance Vought Corp. scientists near Dallas, Tex., reported in late March that they are working on three projects looking toward large-scale use of either calcined gross fission products (CGFP) or separated radioisotopes from fission-product wastes:

Project Artesia. Looking toward wide-ranging use of power reactors and the eventual production of billions of curies of fission byproducts, the group is exploring the use of CGFP heat for conversion of saline water to fresh. Current work is sponsored by the Office of Saline Water, Interior dept., under a Phase 2 contract of $25,500; this covers conceptual design of an experimental test model to produce 240 gal of water/day and using about one megacurie of CGFP. AEC, according to group leader M. A. Welt (formerly of AEC's Hazards Evaluation branch), is expected to support construction of this unit by year-end at an AEC site.

Project Nuclide Heat. Under a $22,000 contract from the Navy's Bureau of Yards and Docks, the Chance Vought group is studying the possible use of either CGFP or separated radionuclides to supply 50,000 to 300,000 Btu's/hr to remote military installations. Four possible approaches are under study, with one to be selected for a conceptual design by December.

Project Double Conversion. This is a power-generator scheme, where beta radiation is converted to light and light to electricity—the traditional scintillation process. Efficiencies of 1–2% have been achieved, according to Welt, but the target is 6–8% which might be reached, it is felt, by a unique approach to modifying radiation wave length. Sponsorship is being sought jointly from AEC and the Navy's Bureau of Ships.

RCA Enters Nuclear Gaging Field

Last month, RCA announced a new line of gamma gages using cobalt-60 and cesium-90 as radiation sources. Nuclear Research Corp., South Hampton, Pa., will supply the sources and RCA's Industrial Controls div. will fabricate the devices at a Philadelphia plant. A company official said that the new line would eventually include beta sources.

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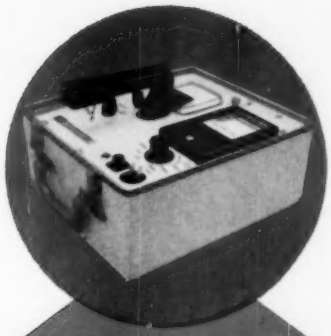

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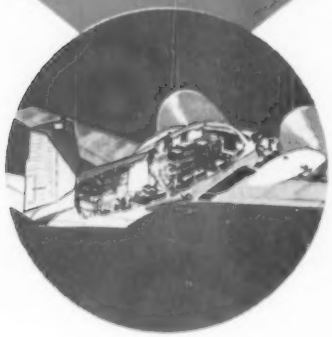

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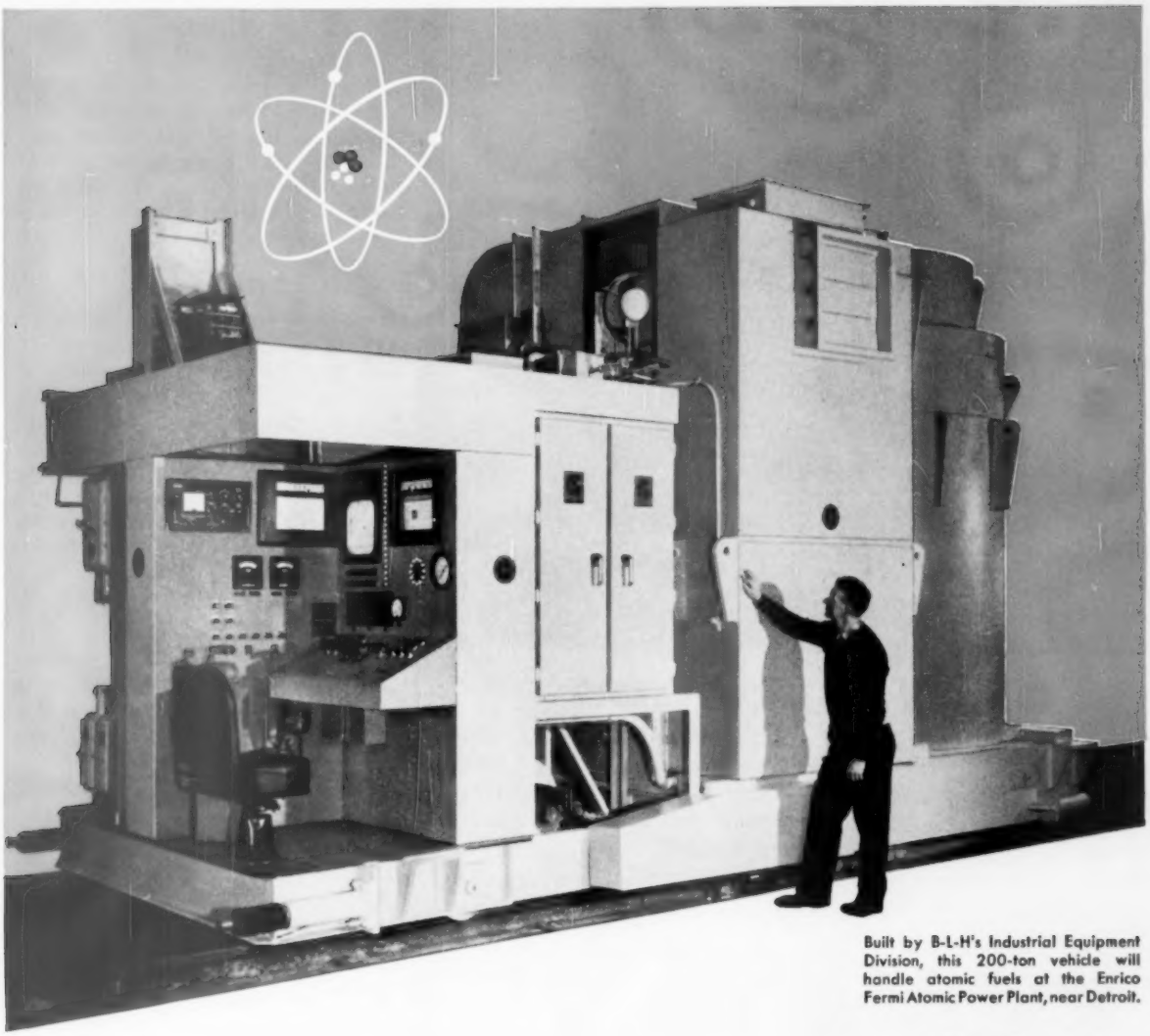

Built by B-L-H's Industrial Equipment Division, this 200-ton vehicle will handle atomic fuels at the Enrico Fermi Atomic Power Plant, near Detroit.

The problem was unique—the problem-solver was B-L-H

In the field of atomic energy there is frequently no precedent. We must often start from scratch. This was the case with the massive and highly complex fuel handling vehicle which the Power Reactor Development Company called on B-L-H to complete final designs for, fabricate and deliver to the Enrico Fermi station.

Self-propelled, this transfer cask car, as it is known, provides means for replacing spent fuel elements in the reactor with fresh fuel elements and for transporting the fuel assemblies safely to and from storage areas outside the reactor building.

Eleven fresh fuel assemblies at a time are accommodated in the cask. Devising special helium-leaktight closures and seals for all cask penetrations was required in order to safely contain an argon atmosphere and insure absolute exclusion of air. A special 10-in.-diam. ball valve which is molecule-tight—i.e., totally leakproof—had to be designed and installed.

Among the many challenging problems was that of providing adequate and economical shielding. The lead shielding was poured in place and inspected by means of gamma probe. In lesser areas depleted uranium castings were used.

Electric arc welding was the primary means of fabrication. All welds were checked by mass spectrometer.

Since its nuclear work is already quite extensive—fabrication of the magnet cores for the four principal accelerators in America, for example—and since its engineering skills and shop facilities are of the highest order, B-L-H should certainly be considered for your upcoming projects. Write for further information.

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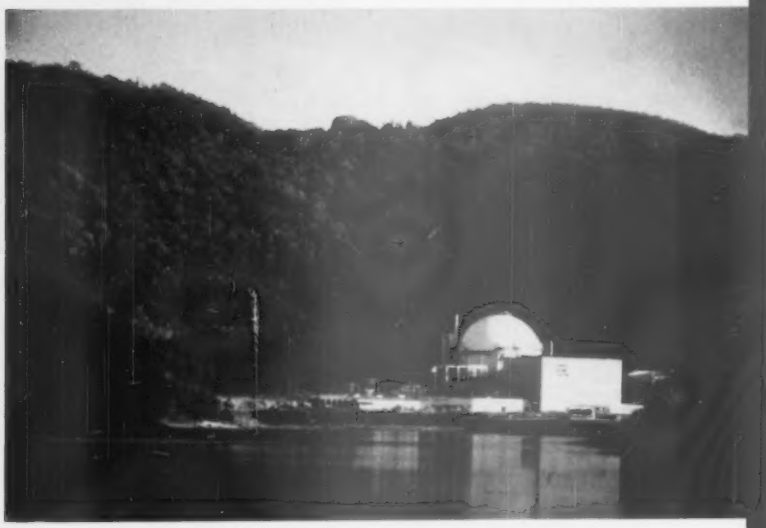
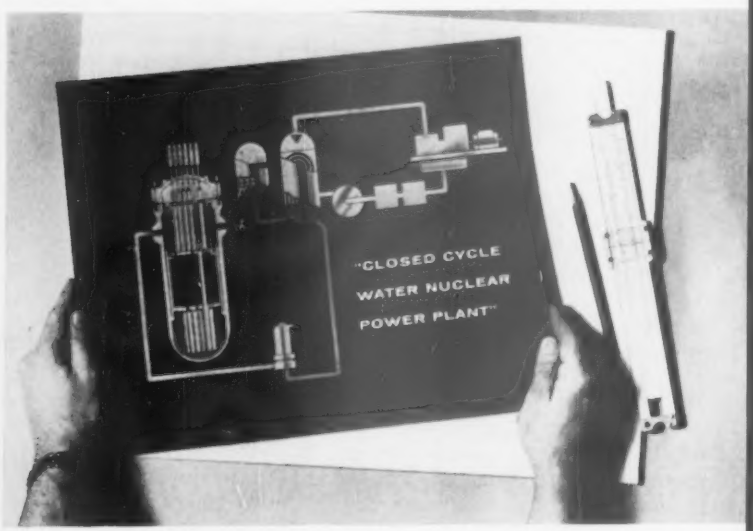


ON THE BOARDS

the new 375-Mwe atomic power plant is a giant step forward in the realm of controlled commercial nuclear power. Projects like this offer to professional personnel the opportunity to take part in the design and development of economic nuclear power plants. Career openings for qualified scientists exist in many areas. Some of these areas are listed in the next column.



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Alloy development on reactor materials and fuels with particular emphasis on control rod and cladding materials. M.S. degree in metallurgy with three years experience in reactor materials.

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To assist customers in the preparation of experiments to be performed in the testing reactor. Includes design of capsules, heat flow and fuel burnup. Also, calculations and liaison with customer engineers during course of the experiment. B.S. degree in engineering with related nuclear experience.

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If you qualify for any one of the above positions, write immediately to: Mr. C. S. Southard, Westinghouse Atomic Power Division, P.O. Box 355, Dept. X-83, Pittsburgh 30, Pennsylvania.

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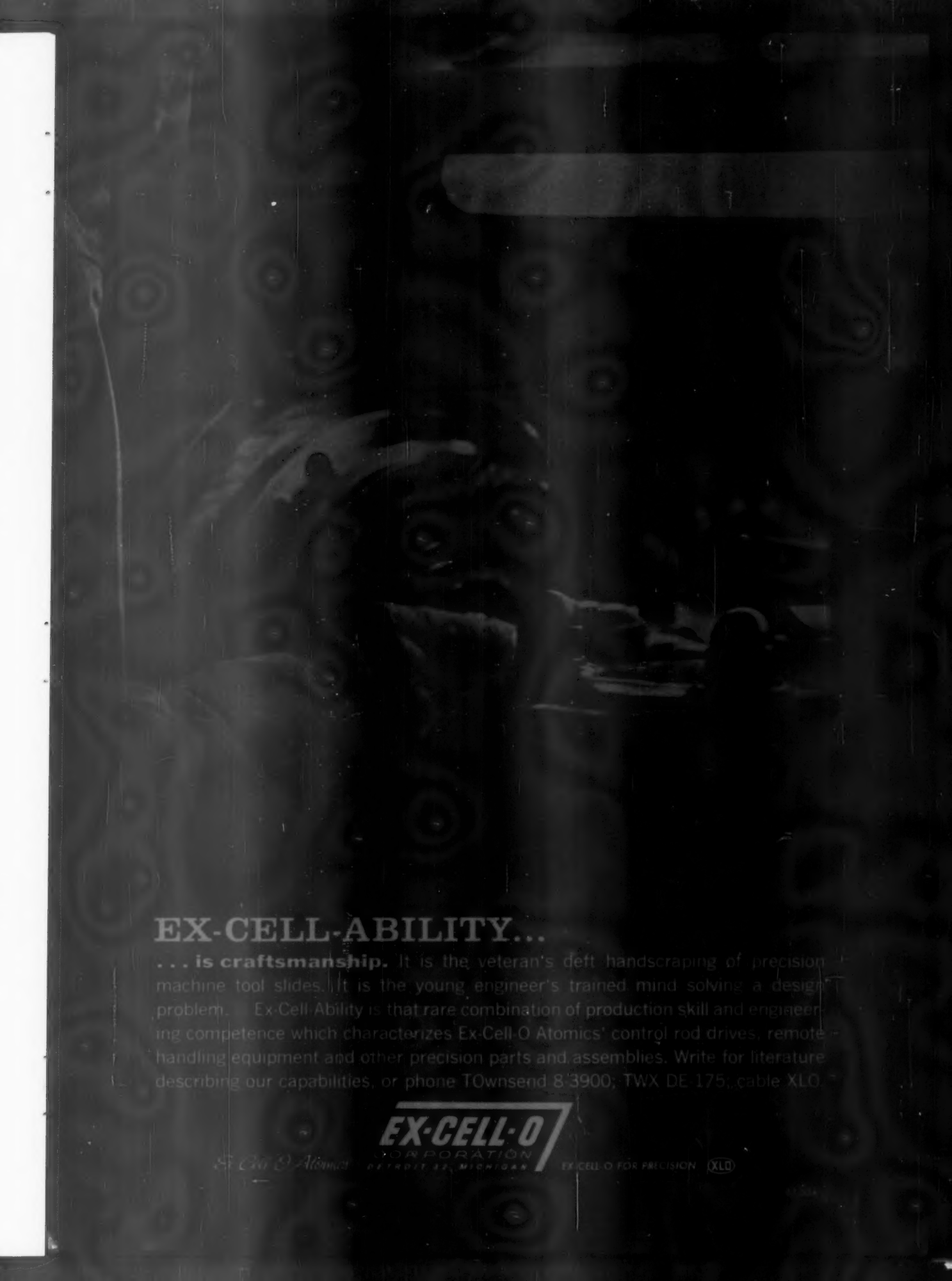

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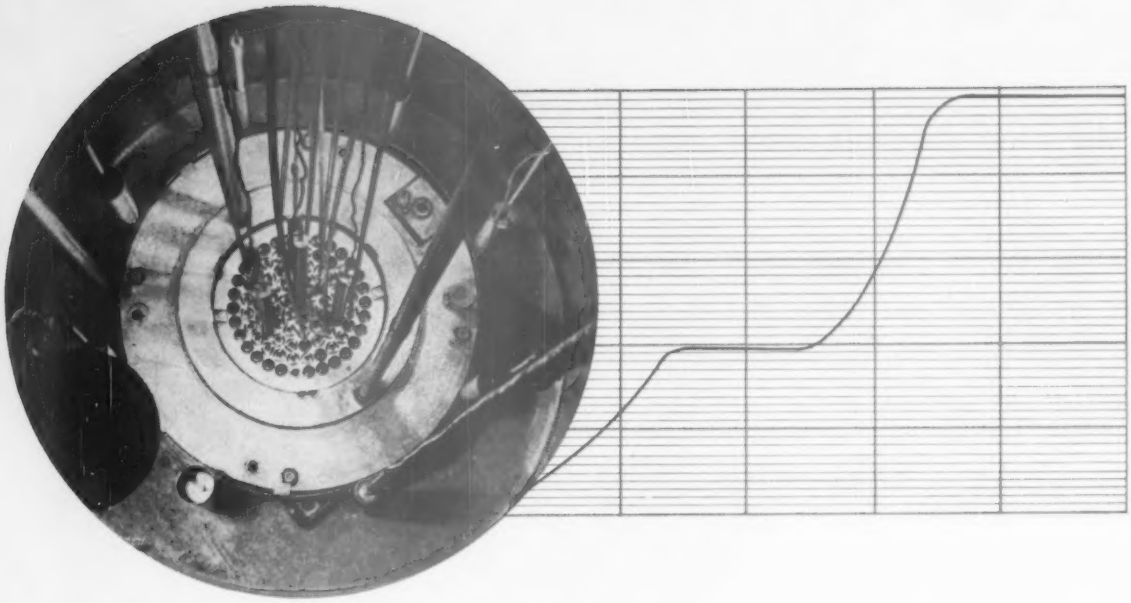

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This increased power, from 100 to 250 kw, is available as an option in the standard TRIGAs which have achieved worldwide popularity — the Mark I below-ground model, and Mark II above-ground version with beam ports, thermal column and experimental shielding tank. More than 20 TRIGAs have been placed in use or soon will be operating on five continents, serving universities, national research establishments, medical centers, and other institutions.

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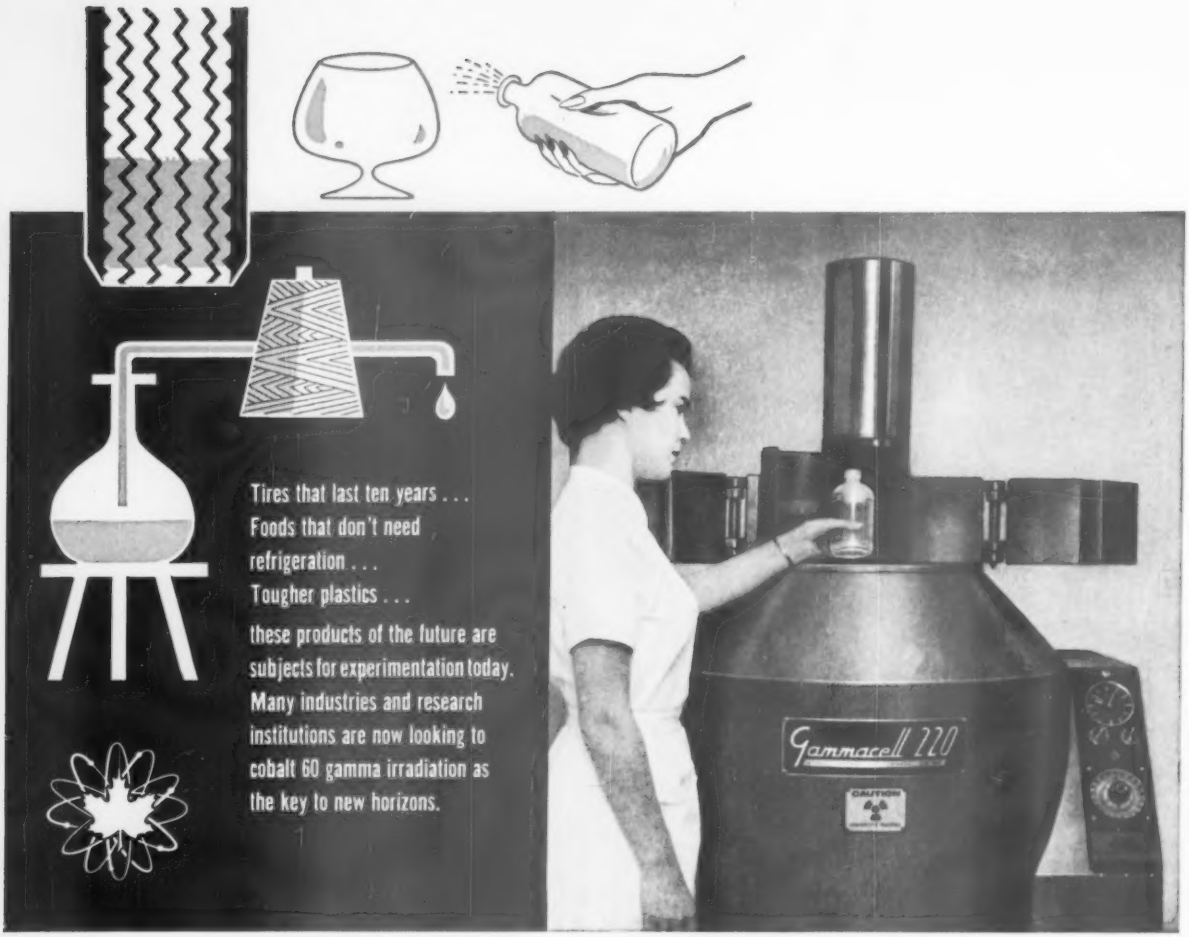
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THE FACTS

Item	RCA-7767	RCA-7764
Stages	10	6
Median Sensitivity (Amperes/lumen)	7.5	0.3
Current Amplification	125,000	5000
Voltage Supply (Volts)	1250	1200
Response Range (Angstroms)	3000-6500 (S11)	3000-6500 (S11)
Max. Response (Angstroms)	Blue 4400	Blue 4400
Max. Rigid Length	4.0"	2.75"
Max. Diameter	0.78"	0.78"

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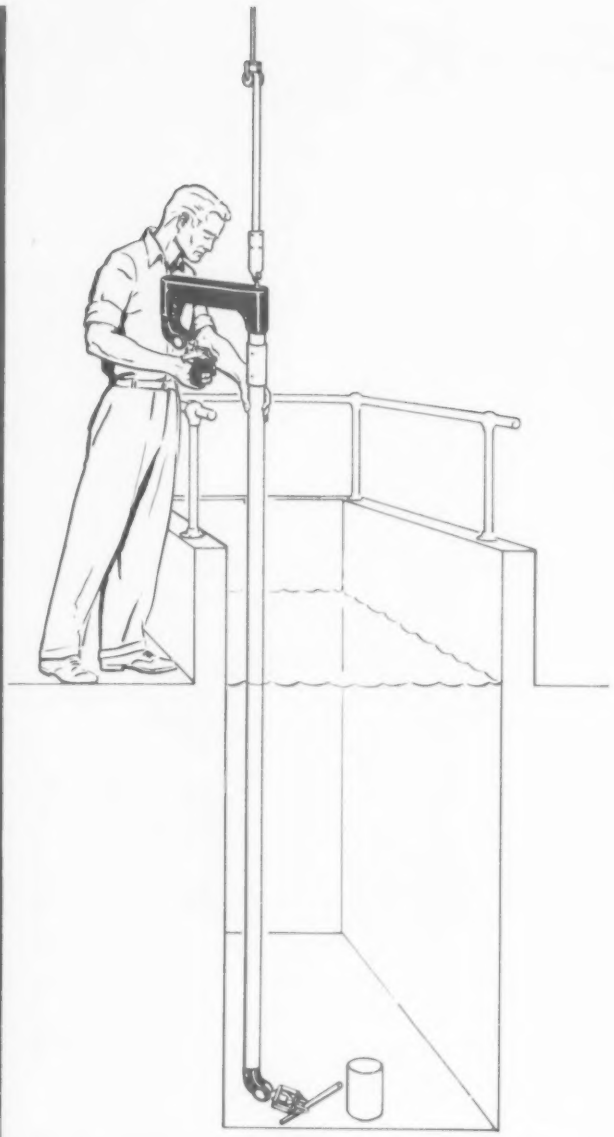
simple and versatile underwater manipulation

Central Research Laboratories'

model B canal manipulator



If your operation has required grappling and fishing at the bottom of a canal or pool, Central Research Laboratories' Model B Canal Manipulator may be the new tool for you. Master-Slave Manipulator type ambidextrous handle, wrist joints, and tongs are coupled by alloy tapes passing through a cross-over housing and long vertical tube. This makes possible dexterous underwater manipulation. All submerged components are stainless steel for maximum corrosion resistance.

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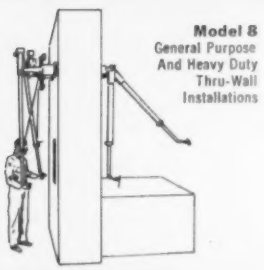
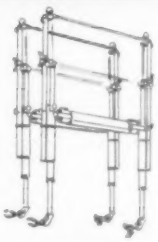
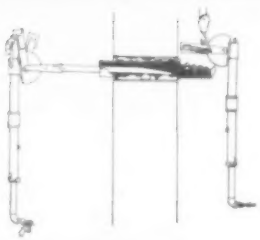


Model 8
General Purpose
And Heavy Duty
Thru-Wall
Installations

Model 7
Restricted Space Installations



Model 4
Over-Wall Installations



Model A Sealed

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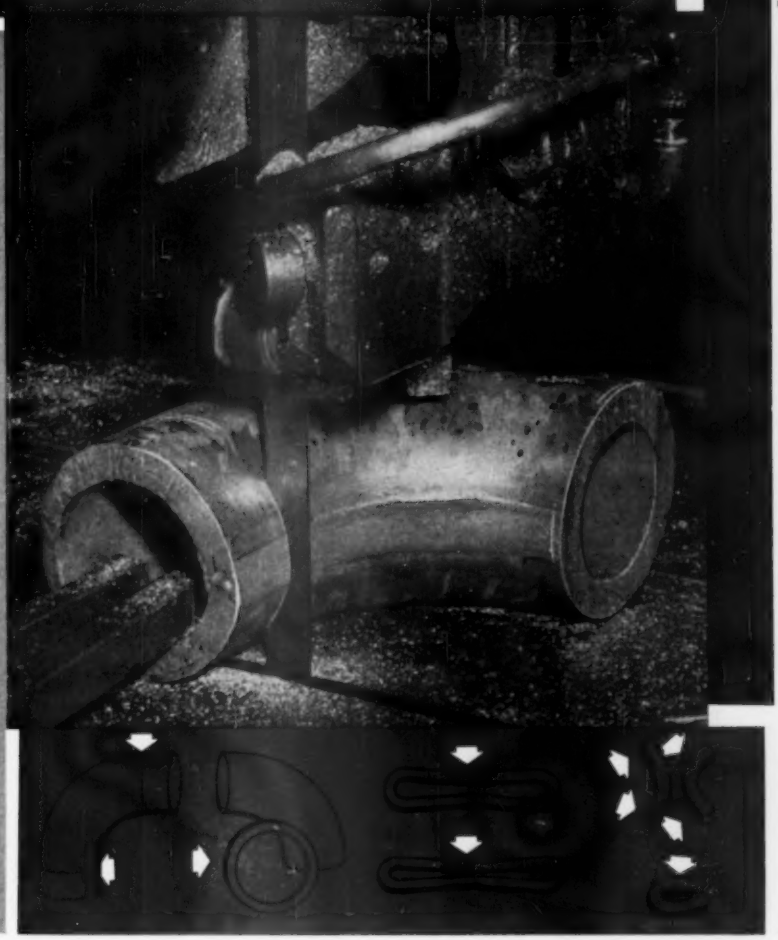

1. Fitting is made with extra long tangents. **2.** Tangents are cut off both ends. **3.** One of the resulting rings is flattened in a press, in accordance with specifications, and closely examined for possible defects. **4.** For welded-type fittings a section of the other ring, including weld, is bent back upon itself, and inspected for evidence of fissuring or other discontinuities.

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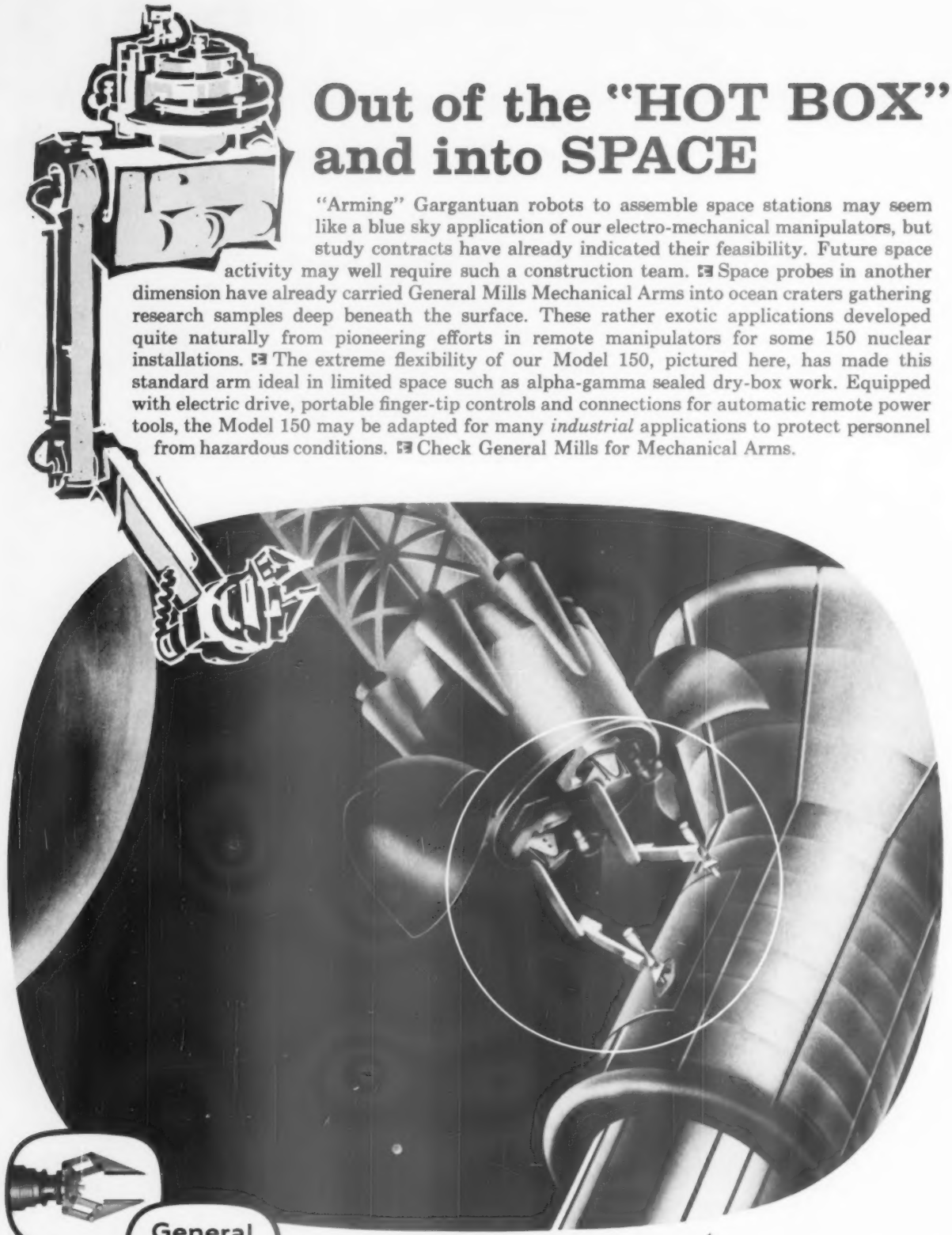

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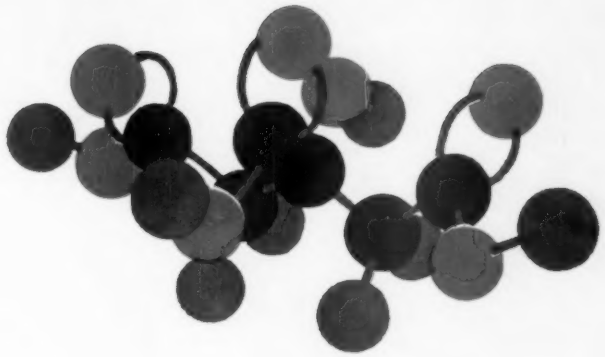

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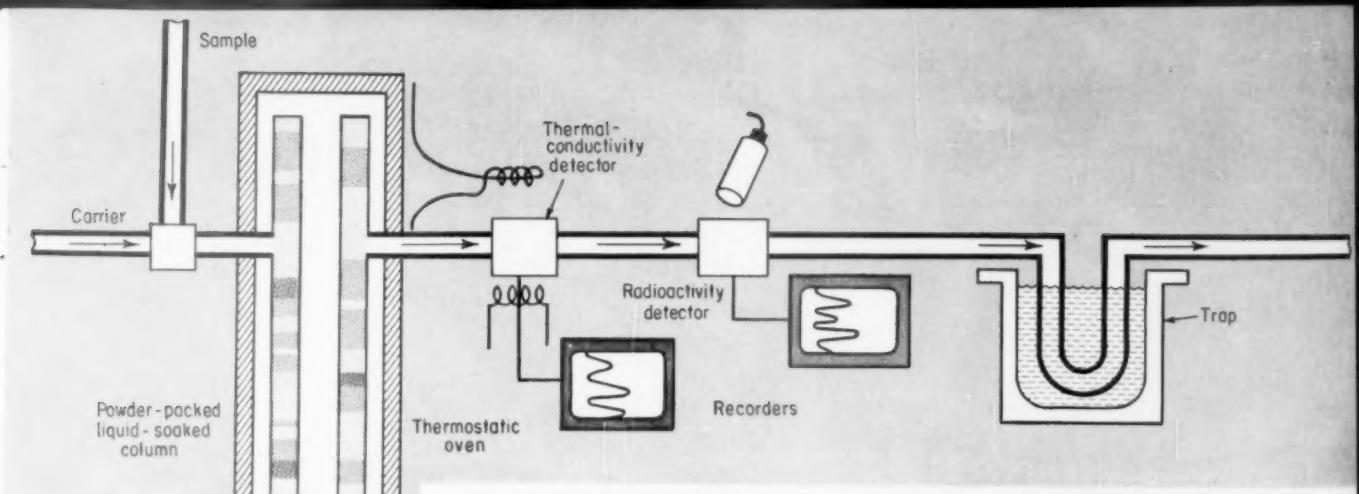


FIG. 1. GAS CHROMATOGRAPHY APPARATUS separates components of gas mixture by allowing carrier gas to carry them through liquid-bearing column of powder. As components emerge, thermal-conductivity cell and radioactivity detector indicate arrivals. Traps can be used to isolate different components

Labeled Organics in Gas Chromatography

When a mixture is separated into its components by the relatively new technique of gas chromatography, radioactive labeling of appropriate components adds new dimensions to the analysis

By FULVIO CACACE, *University of Rome, Rome, Italy*

RADIOACTIVE LABELS can play several significant roles in the relatively new separation technique of gas chromatography. When the purpose is analysis, radiotracers often make it possible to recognize separations with much greater selectivity than one can have with the usual detectors. When the purpose is separation for later use of one or more of the components, different radioactive components can often be separated more effectively by gas chromatography than by any other method.

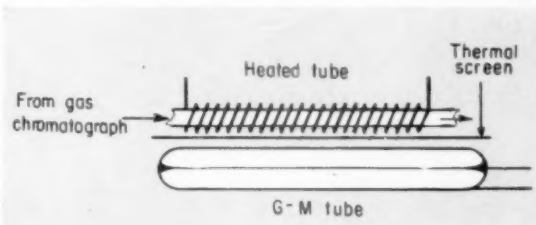
Practically all available types of radioactivity detectors have been applied to the detection problems that arise in gas chromatography. In particular, several methods have been applied to make possible detection of C^{14} and tritium in the effluent gases. A recent extension of this technique makes possible the separate assay of C^{14} and tritium in doubly labeled compounds. This consists in breaking down the organics into carbon dioxide labeled with C^{14} and either water, which can be removed, or tritium-labeled hydrogen gas, which can be separated and counted by itself.

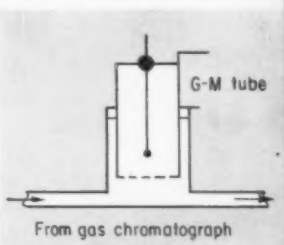
Gas Chromatography

Gas chromatography—also called "vapor-phase chromatography," "gas-liquid partition chromatography," "vapor fractometry"—is a relatively recent and rapidly expanding analytical technique introduced by James and Martin in 1952 (*1*). As in other chromatographic methods one uses a separating column packed with a "stationary phase a low-volatility liquid supported by an inert solid of large surface area (Fig. 1). The mixture to be fractionated is carried by a current of gas,

FIG. 2. G-M DETECTOR counts gammas as effluent passes through heated tube

FIG. 3. SPECIAL MOUNTING puts soft-beta emitters near thin-window G-M tube





the "mobile phase."

Because of their different volatilities and solubilities in the stationary liquid, various components of the mixture emerge from the column at different times, and their concentrations in the effluent gas can be separately determined by a suitable detector.

The volume of carrier gas—the "retention volume"—required to elute a certain substance from the column under a given set of experimental conditions is characteristic of the substance, and the integrated detector response (the area under the curve) depends on the amount of the substance.

In addition, by collecting in separate traps the compounds emerging from the column, one can use gas chromatography to obtain the components of a complex mixture in very pure states.

Advantages. The most striking advantages of gas chromatography over early separation methods are its great efficiency in resolution of mixtures, the small amount of sample required and the short time required.

The efficiency of gas-chromatograph columns can be evaluated in terms of "numbers of theoretical plates." In a conventional distillation column a theoretical plate is a discrete elementary stage in which a complete equilibrium between liquid and vapor phases is reached.

A good laboratory distillation column may possess an efficiency of 50 theoretical plates and require some tens of grams of the mixture to be analyzed. On the other hand at present it is common practice to use gas-liquid partition columns having efficiencies that correspond to more than 1,000 theoretical plates per meter, suitable for operation up to 250°–350° C. The most widely adopted detector, the thermal-conductivity gage, allows one to detect less than 1 mg of an organic substance in the effluent gases.

Coated capillary columns with very large numbers of theoretical plates can be used with hypersensitive detectors for special purposes—for example, for separation of as little as 0.005 mg of compounds having a volatility ratio close to unity.

Detectors for Continuous Analysis of Gas-Chromatography Effluents

Type	*References*	*Nuclide**	*Notes*
G-M tube, external flow	*10–12, 20*	Br^{80},Br^{82}	For hard-beta or gamma emitters.
Thin-window G-M tube, external flow	*13–16*	N^{13},C^{14},I^{131}	For weak-beta emitters the efficiency is low.
Proportional counter, internal flow	*12, 17–20*	H^3,C^{14}	By employing a methane-helium mixture as counting gas, high efficiency is obtained; the counter can be operated up to 200° C. A special device has been described to avoid poisoning of the counter by large amounts of the eluted compounds at very high temperature.
External flow scintillation counter	*11, 12, 21*	Br^{80},Br^{82}	For hard-beta or gamma emitters.
Liquid scintillation counting device	*24, 25*	H^3,C^{14}	Good efficiency for weak-beta emitters. Activity of eluted compounds is recorded additively.
Ionization chamber	*26–32*	H^3,C^{14}	Activity analyses are not affected by chemical natures of eluted compounds. Chambers have been developed for operation up to 240° C. Sensitivity for C^{14} and H^3 is satisfactory.
Ionization chamber after chemical conversion	*33, 34*	$H^3 + C^{14}$	Activity of C^{14} and tritium in doubly labeled compounds can be separately assayed in one operation.

* Nuclides reported are those for which analysis has been described in the listed papers. Many other nuclides can be assayed with the apparatuses described in the table.

Tracer Separation

It has been recently stated (*2*) that "gas-phase chromatography, since its discovery by James and Martin in 1951, has done more in its applications to the field of hot-atom chemistry than any other experimental technique brought to bear on these problems in the last 15 years."

A common—and difficult—problem is the isolation of radioactive compounds from mixtures containing a large number of carrier-free impurities with similar structures and properties. Such problems occur frequently in (a) preparation of tritiated molecules by the Wilzbach gas-exposure method

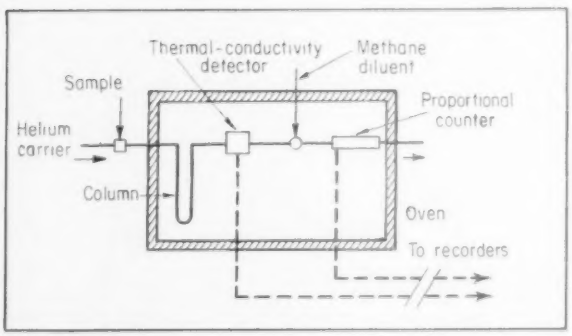


FIG. 4. FOR C^{14} AND TRITIUM proportional flow counter resides in oven. Adding methane makes counting gas of mixture

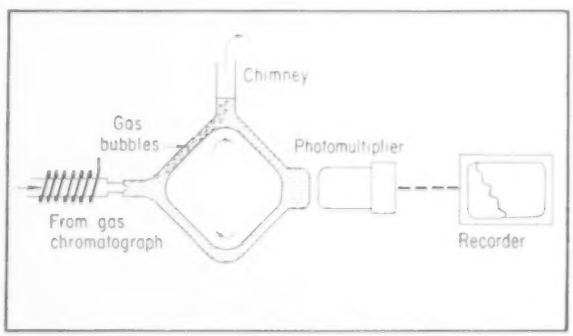


FIG. 5. LIQUID-SCINTILLATION SYSTEM bubbles gas through solution. Bubbles stir liquid, and radioactive components dissolve

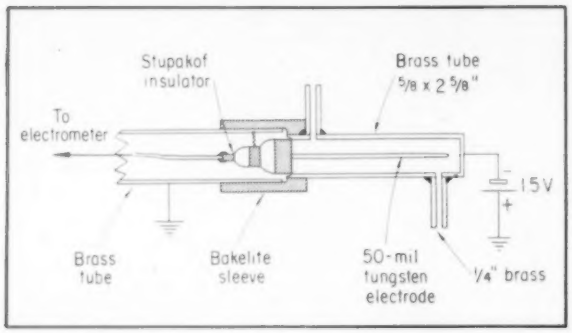


FIG. 6. SMALL-VOLUME FLOW CHAMBER is especially sensitive to C^{14} and tritium. Chamber will operate at 100° C

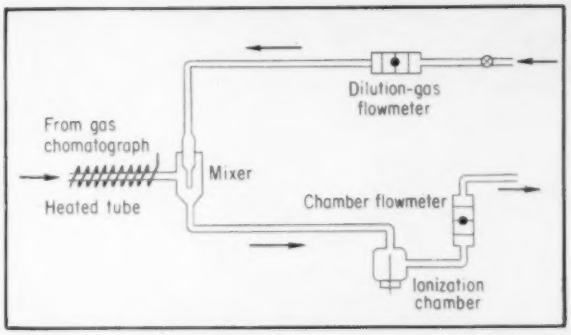


FIG. 7. FOR WORK AT ROOM TEMPERATURE gas mixer dilutes effluent gases so that they do not condense in chamber

and similar techniques, (b) the study of Szilard-Chalmers processes in organic systems, (c) identification of radioactive intermediates in tracer investigations of metabolic pathways and (d) hot-atom chemistry of tritium, carbon and halogens.

For this sort of problem, whenever compounds of reasonable volatility are involved, gas chromatography is by far the most practical and efficient separation and purification method at our disposal. Its use is expanding at an exceptional rate. A number of different experimental techniques have been developed in recent years with the ultimate scope of separating and purifying labeled molecules by gas chromatography and assaying their radioactivity. Methods and apparatuses employed can be separated into those for batch operations and those for continuous ones.

The first group deals only with chemical and radiochemical purification of one or more labeled substances contained in a mixture. The gas chromatograph is operated essentially as a distillation column having a very large number of theoretical plates. Purified compounds are collected separately in the effluent gases as they leave the partition volume, their elution peaks being followed by the mass detector of the chromatographic apparatus. Radioactivities are then assayed in the usual way.

The second group is designed for continuous measurement of radioactivity in gases flowing from the chromatograph. In such a way one obtains a simultaneous mass and activity analysis, which allows detection and measurement of both the amount and radioactivity of the individual components.

This continuous method of analysis offers the remarkable advantage of giving a detailed picture of all the radioactive volatile compounds—even if carrier free. In addition, from the ratio between the mass-peak area (recorded by thermal-conductivity gage) and the radiochemical-peak area, one can compute the specific activity.

Methods of Analysis

Let us now consider various techniques developed for gas chromatography of labeled substances.

Batch analysis. The simplest apparatus required for batch analysis is a gas-chromatography unit with an outlet that can be connected with a U-shaped glass tube cooled with a dry-ice or liquid-nitrogen bath. When the mass detector shows elution of the desired compound from the column, the trap is inserted and the labeled substance is collected (*3–7*). The simple U tube can be replaced by a manifold trap that permits one to trap a number of radioactive compounds.

Wolf showed that useful information on the radiochemical purity of labeled compounds, passed through a gas-chromatography column, can be obtained by collecting in two separate traps the "head" and "tail" of each elution peak and comparing their specific activities; any difference demonstrates the presence of impurities (*3*).

Improved trapping devices have been developed recently for situations in which radioactivities of purified substances are to be assayed with a scintillation counter (*8*). Gases leaving the chromatograph are passed over anthracene crystals (scintillation grade) coated with silicone oil, which dissolves the organic vapors very efficiently. Successive absorption cartridges can be exposed to the gas stream without interruption of analysis simply by rotating a turntable.

The antracene-crystal cartridges are of standard size and can be directly mounted in a beta spectrometer. This improved assembly is now commercially available as a beta-spectrometer accessory (Packard Model 830 Tri-Carb Gas-Fraction Collector).

In a very recent paper, W. E. Harris has reported the use of charcoal absorption tubes for efficient trapping of Br^{80} and Br^{82} compounds (*9*).

Continuous analysis. The experimental arrangement for continuous analysis is shown in Fig. 1. On leaving the gas-chromatograph column eluted compounds are passed first through the thermal-conductivity cell and then through the radioactivity detector, the outputs of both being fed into two synchronized recorders.

The main difference between various apparatuses is in the radioactivity detector, which is chosen according to the radionuclide to be assayed.

Radioactivity Detectors

Some of the peculiarities of the gas-chromatography apparatus pose perplexing problems for the designers of radioactivity detectors. Since the effluents are parts of a gas stream, there is always the matter of bringing the sample into contact with the detector. This is aggravated when the radiation is soft as it is in C^{14} and tritium. Moreover the gas stream is usually hot. If the detector is not operated at a high enough temperature, one faces the danger that components of the effluent will condense in the detector.

G-M counting. With gamma or hard-beta emitters, radioactivity in effluent gases can be detected simply

with a G-M tube adjacent to the heated, thin-walled outlet tube of the gas chromatograph (Fig. 2) (*10–12*). The counter is mounted below the flow tube and separated from it by a thermal screen, a thin sheet of aluminum foil.

Figure 3 shows the device employed by Tobin, Kokes and Emmet in the analysis of C^{14}-labeled compounds (*13*). Effluent gases flow through a compartment enclosing a mica-window G-M tube. A similar assembly, employing two mica-window G-M counters, has been adopted by Russians (*14*) and by Napier and Green (*15*) for analysis of C^{14}- and I^{131}-labeled compounds.

A device that includes a 2π proportional counter, viewing the opposite Mylar windows of a glass cell through which gases leaving the chromatograph are passed, has been recently described for the analysis of N^{13}-labeled substances (*16*).

Wolfgang and MacKay (*17*) have developed a window counter in which gases from the chromatograph flow through a thin-walled tube inserted into the sensitive volume of a proportional counter. By a proper choice of tube-wall thickness they get satisfactory discrimination between C^{14} and tritium.

But the efficiency of external G-M and proportional counting devices is small for weak beta-emitters; tritium cannot be detected.

Proportional counting. The counting efficiency for C^{14}- or tritium-labeled compounds can be markedly increased by passing the effluent gases directly through a flow proportional counter. The detector must withstand high temperatures to prevent high-boiling vapors from condensing within the sensitive volume. Only in the analysis of very volatile or trace compounds, can the counter be operated at room temperature.

For example, Gordus, Sauer and Willard (*12, 18*) use a 10-ml counter for assay of traces of tritiated compounds. Since mixtures of methane with organic compounds have satisfactory counting properties, methane has been chosen as carrier gas despite the low sensitivity of the katharometer caused by the small differences between thermal conductivity of methane and those of most organic substances.

A more elaborate device has been recently described by Wolfgang, Rowland and colleagues (*17, 19*). The gas chromatograph (Fig. 4) is operated with helium as carrier gas so that one obtains high sensitivity with the katharometer. On leaving the column and before passing through the proportional counter the helium is diluted with methane. The resulting mixture (about equal volumes of methane and helium) is suitable for proportional counting in an especially designed tube.

The proportional plateau of such a counter is more than 50 volts long even if the detector is operated in the chromatograph at temperatures up to 200° C. Since its sensitivity for C^{14} and tritium is great, the Rowland and Wolfgang equipment is very efficient in the analysis of C^{14}- or tritium-labeled compounds. (Counter efficiency is $\sim 95\%$, background in a 1-in. lead shield being 25 cpm for a tube having ½-in. i.d. and 4-in. active length.)

A drawback in the use of proportional counters is the possibility that their efficiencies will be affected by large amounts of organic substances emerging from the chromatograph column, especially at very high temperatures.

A satisfactory method to overcome the poisoning of the counting gas by the organic compounds emerging from the column is to add a constant amount of the poisons to the gas (*20*). The users obtain satisfactory operation of their proportional counter, heated to 210° C, for the analysis of tritiated toluenes and nitrotoluenes.

Scintillation counting. In the analysis of substances labeled with gamma- or energetic-beta-emitting nuclides scintillation counters have been used. Effluent gases pass at the bottom of a thin-walled glass thimble (*11, 12*), or through a thin-walled glass spiral (*21*) fitted on a sodium iodide crystal.

To prevent organic vapours from condensing in the thimble, Evans (*12*) heated the whole detector to 200° C in spite of the possible cracking of the crystal and its sensitivity drop caused by long operation at high temperature. For the analysis of C^{14}-labeled gases two similar devices have been used successfully, one including a plastic-scintillator-walled cell (*22*) and the other a hollow plastic scintillator in the form of a spiral (*23*).

In a completely different approach, employing a liquid scintillator, gases leaving the gas-chromatograph unit are injected through a heated metal tube into a cooled glass circuit of the shape shown in Fig. 5 (*24, 25*). The glass circuit is filled with a solution of organic scintillator. Before they escape from the chimney, the carrier gas bubbles cause the liquid to circulate in the whole glass trap.

Organic vapors condense and dissolve in the cold solution; vigorous circulation promoted by the gas stream ensures complete mixing within a few seconds. The main body of the trap, the bulb, looks at a photomultiplier tube, and the photomultiplier output after amplification is measured with a ratemeter connected to a recorder.

In this case radiometric analysis is of integral type, the radioactivity of the labeled substances emerging from the column being recorded additively. As a consequence, when a compound of high specific activity is eluted, all the remaining radioactive substances must be counted on the highest range of the ratemeter. To minimize this inconvenience a manifold is connected to the trap so that one can change the scintillator solution at suitable times.

This interesting device appears suitable for highly efficient counting of

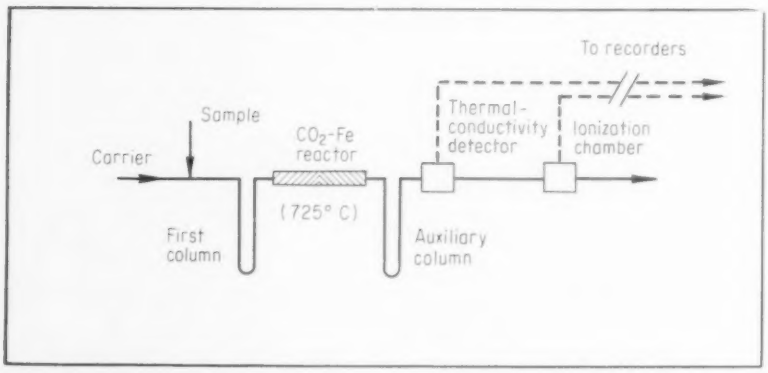


FIG. 8. DOUBLE-SEPARATION SYSTEM permits separate counting of C^{14} and tritium

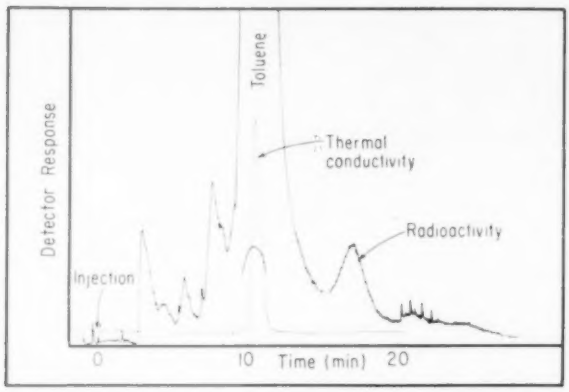


FIG. 9. WILZBACH-LABELED TOLUENE shows presence of carrier-free products in amounts so small that only radioactivity detector responds to them, mass detector does not

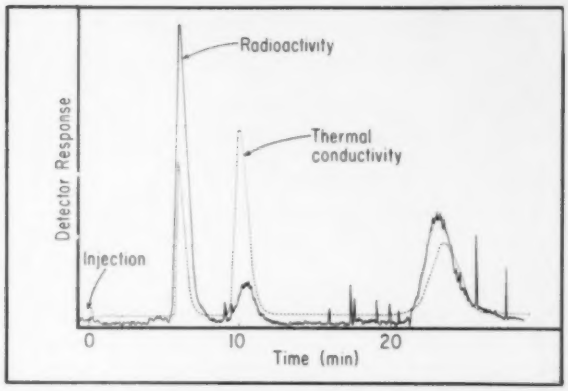


FIG. 10. PURIFIED RADIOACTIVE COMPOUNDS have mass peaks (shown by thermal-conductivity detector) in coincidence with peaks of radioactivity. The coincidence proves the purity

C^{14}- and tritium-labeled compounds. The detector geometry is satisfactory because most (72%) of the scintillator is contained in the glass bulb.

In the analysis of tritiated samples, however, single-phototube detectors give a rather high background if they are adjusted for good counting efficiency. (The counting efficiency of this liquid scintillator device is 20% for tritium with an electronic noise of 3 cps and a background of 12 cps.)

Ionization chambers. A flow ionization chamber coupled with a vibrating-reed electrometer has been used by Wilzbach and Riesz, who include the ion chamber in the oven of the gas chromatograph and insert it with insulating (Nylon) fittings, directly after the thermal-conductivity cell (*26*). The chamber (Fig. 6) has a volume of ~ 8 ml and is especially designed to be operated up to 100° C. Because of its small volume, the Wilzbach chamber has a very high resolving power; its efficiencies for C^{14} and tritium are respectively, 20% and 75% when nitrogen is employed as carrier gas. It will detect about 4×10^{-9} curie of tritium in one peak when the peak has a width smaller than the chamber volume.

B. M. Tolbert has built ionization chambers suitable for operation at 225° C (*27, 28*). They have a working volume of 9 ml. Teflon being used for the main insulator to avoid stress currents that originate in ceramic insulators at high temperatures. Improved chambers described by Dobbs (*29*) and by Mason, Dutton and Bair (*30*) have been operated at temperatures up to 240° C. With these chambers 10^{-7} curie of tritium in one peak has been measured. More recently Dutton has worked out an apparatus that is far superior to the earlier system.

Ionization chambers have valuable features. Their response is independent of the chemical constitution of both eluted compounds and carrier gas; they afford absolute measurement after one calibration; they can be disassembled for decontamination purposes without destroying calibration. The sensitivity of the ionization-chamber – vibrating-reed-electrometer assembly is quite satisfactory for analysis of C^{14} and tritium.

To avoid troubles arising from the construction and operation of chambers at high temperatures, I have developed an apparatus that operates at room temperature (Fig. 7) (*31, 32*). The gas stream flowing from the chromatograph is diluted with a current of pure carrier gas in a suitable mixer. The dilution is effected in such a way that the total flow rate is a constant at which the ionization chamber has been calibrated once for all.

The radioactivity measurements are consequently independent of the carrier flow rate chosen for separation. Moreover the relatively large volume of gas in which the vapors leaving the column are diluted eliminates the need of heating the ionization chamber. About 5×10^{-9} curie of tritiated compounds can be detected in one peak.

As a final advantage with a system of this type, a chamber having a volume of about 100 ml—very efficient indeed for the measurement of C^{14} and tritium—can be used without appreciable loss of resolving power, owing to the increased speed of the radioactive gas.

Analysis After Conversion

My colleagues and I have recently reported a new method for radiometric analysis of C^{14}-labeled substances separated in a gas-chromatograph column (*33*). It is based on conversion of the organic vapors in the effluent into water and carbon dioxide. The gas stream from the column flows through a silica tube heated to 750° C and filled with copper oxide. The combustion gas mixture (CO_2 and H_2O) is dried in a silica gel trap before the carbon dioxide passes through the thermal conductivity cell and the ionization chamber. Regardless of the separation temperature both mass and radioactivity detectors are operated at room temperature.

This technique affords a number of advantages as long as the sensitivity of the katharometer is markedly improved when operated at room temperature and high-boiling organic substances are prevented from condensing in the chamber. Moreover the chamber measures the activity of one gas—the carbon dioxide—and is operated at constant temperature and flow rate.

A still more sophisticated assembly for analysis of compounds doubly labeled with C^{14} and tritium is shown in Fig. 8 (*34*). Leaving the column organic vapors go into a silica tube packed with copper oxide and reduced iron heated to 725 ± 10° C, and the gases are converted into a mixture of carbon dioxide and hydrogen.

These gases are separated in an auxiliary column and passed through the mass and radioactivity detectors. Thus two separate peaks (due to carbon dioxide and hydrogen, respec-

tively) correspond to each organic. From the ratio of the areas in the carbon-dioxide and hydrogen peaks deduced from the katharometer recording one can calculate the empirical formula of each eluted compound.

Radioactive Separations

A few examples of gas-chromatography applications to separation of radioactive substances will give the reader a general picture of the results that can be obtained.

One of the most difficult tasks in hot-atom chemistry is identification of labeled substances produced by recoil of short-lived nuclides. Often the time required for efficient purification and isolation (including fractional distillation and paper chromatography) is far too long in relation to the half-life of the nuclide involved. Gas chromatography has succeeded in determining the distribution of 10-min N^{13} activity [produced by the $C^{12}(d,n)N^{13}$ reaction] in organic compounds and in carbon tetrachloride (*16*). In such a way the predominant production of radioactive cyanides was demonstrated; N^{16}-labeled nitrogen and nitrogen oxides have also been detected.

Application of gas chromatography to preparation of pure tritiated compounds by the Wilzbach gas-exposure method is shown in Fig. 9.

You can see that toluene is contaminated by a number of carrier-free radioactive impurities, including benzene, cyclohexane, cyclohexene and hydrogenated toluenes. The impurities contain a relatively large percentage of the total activity despite their very small amounts—too small to be detected in the mass analysis. By collecting in separate traps the peaks emerging from the column, one can use gas chromatography also as a preparative technique; Fig. 10 shows the radiochemical purity of organic compounds (prepared by the Wilzbach method) previously purified by gas chromatography.

A typical application of gas chromatography to tracer work with labeled molecules, in the field of organic radiation chemistry, is shown in Fig. 11. The mass and activity analysis of a mixture of C^{14}-labeled methane and C_3H_8 (*35*) irradiated to 10^8 rads with gammas is shown.

The efficiency of gas chromatography in the separation of substances having a strictly similar volatility makes it possible in some instances to differentiate isotopic molecules—molecules that are identical except that they contain different isotopes of a given element. Thus Wilzbach and Riesz demonstrated measurable differences between the retention volumes of ordinary cyclohexane and cyclohexane containing tritium atoms (*36*).

In the analysis of highly radioactive gases (krypton and xenon), during absorption on the column the heat produced by radioactive decay causes a local rise of the temperature (*37*). Hence, the rear of the absorption band tends to move faster than the front, with a remarkable contraction of the band width.

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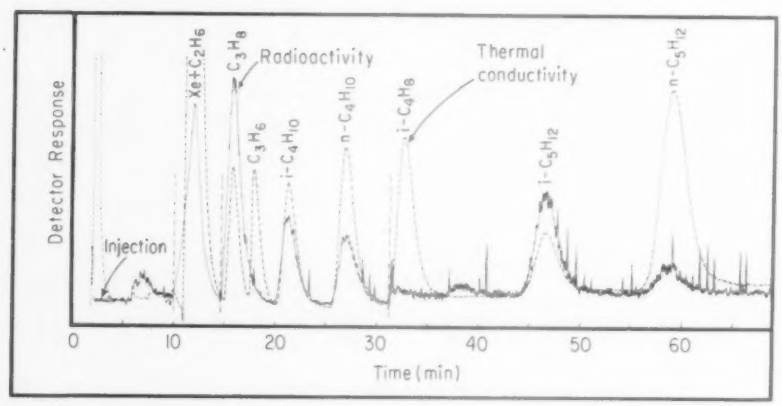
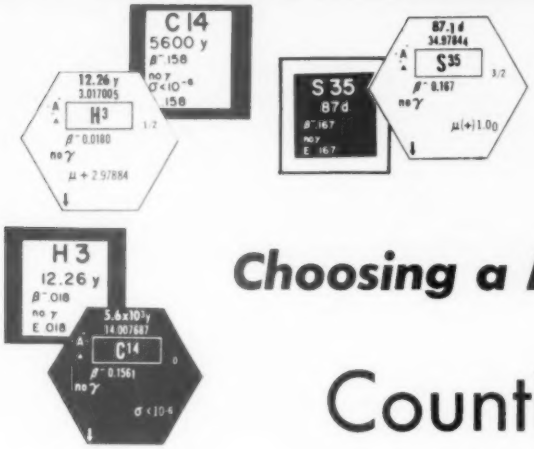


FIG. 11. MIXTURE OF $C^{14}H_4$ AND C_3H_8 irradiated with gamma rays shows production of labeled hydrocarbons ranging from ethane to hexanes in its gas chromatogram



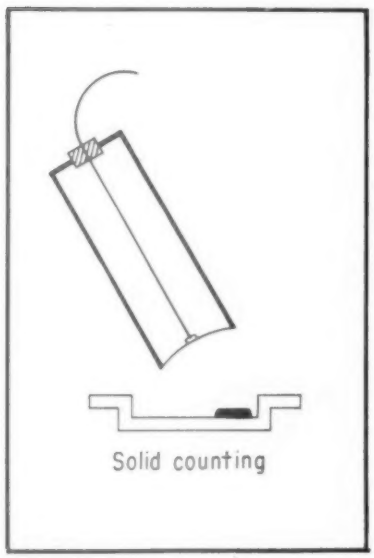
Choosing a Method for...

Counting Soft Betas

For counting the soft betas of C^{14}, S^{35} or tritium you will use a solid counter, gas counter, ionization chamber or scintillator. Here are some criteria that will help you choose among them

By DAVID R. CHRISTMAN, *Brookhaven National Laboratory, Upton, New York*

SOFT-BETA EMITTERS repeatedly pose problems of detection. Organic chemists, for example, must choose among several fundamentally different methods for determining the activity of C^{14}, tritium and S^{35}, the radionuclides that they use most often. Each of these nuclides can be measured as a solid, a gas or a liquid. Each can be measured by proportional or G-M counting, with ion chambers, and with solid or liquid scintillators. Among these methods each has features that make it advantageous under certain conditions, but no one of them is a panacea for all of the organic chemist's counting problems. In fact with each method some counting problems arise that cannot be solved directly without one of the other methods. How does one choose a particular method from the standpoint of disadvantages, problems, applicability and cost?



We shall see that for a laboratory that can afford more than one counting system best results can be had with a combination of several methods. The combination that best serves an individual need varies with both total sample load and type of samples. For a light sample load gas proportional counting appears to be the most universally effective method (except for air monitoring and very active samples, for which ion chambers should be used). This is especially true if small disintegration rates are frequently encountered. For larger sample loads and large samples with low specific activities a liquid-scintillation counter is best—but only with a gas method available for use with samples that cannot be easily handled with scintillation methods.

How Do We Count?

Since the characteristics of different radiation-detection methods can be found elsewhere (for example, Ref. *1*), we can limit ourselves here to a few remarks on statistics and a comparison of the methods (See table, Page 52).

The precision with which any radioactivity determination can be made is limited by the total number of events that affect the detector. The standard deviation of any net counting rate can be computed by standard methods (*1*), and better precision cannot be obtained regardless of the amount of care taken in handling the sample and in counting. In actual practice one cannot do more than approach this precision (see Ref. *2* for a specific example). Under normal conditions it is almost impossible to count samples with a total standard deviation of better than $\sim \pm 1\%$, even with reasonably active samples. At low counting rates even that precision can only be approached with long counting periods and special equipment (heavily shielded anticoincidence counters and special circuitry) not normally available (*3*, *4*). Such counters are usually used only for such applications as carbon dating (*4*) and are quite expensive and considerably more difficult to maintain than ordinary counters used in most laboratories. Let us be concerned only with ordinary equipment more or less readily available.

It is convenient to discuss gas counters mainly as proportional rather than G-M counters because of the considerable advantages inherent in proportional counting. Most of our remarks apply equally to both types, however. The chief advantage of the proportional over the G-M counter lies in the very much greater counting rates that they can accommodate because of the very short dead time inherent in proportional operation. A G-M counter becomes virtually useless at counting rates over ~25,000 cpm, but a proportional counter can be used at rates as great as several million counts

per minute if one makes appropriate coincidence corrections (*1*, *5*). Furthermore, proportional counters appear to be somewhat less sensitive to many impurities than are G-M counters under similar conditions. Both methods have been successfully used for internal gas counting of both C^{14} and tritium (*6*, *7*), but there is no apparent technical advantage to G-M counting except for the less sophisticated electronics needed for G-M operation. Points of difference are also shown in the table. The individual characteristics of the different physical forms in which nuclides are counted are also important.

Solid Counting

Probably more widespread at present than any other method of counting beta emitters is solid counting chiefly because of its relative cheapness. It is, of course, the least sensitive method, and generally, the least precise of those discussed here (see table). Constant standardization and correction for such phenomena as backscattering and self-absorption (*8*) are necessary, unless "infinitely thick" samples are used (a thickness in which all emitted particles from the lowest layers are absorbed by the sample itself). Great care must be taken to ensure uniform deposition of the sample on the counting planchet, and consistent counting geometry is needed if samples are to be compared. Counters are used either with a thin window between the sample and the counter or with the sample actually inside the counter.

With organic samples a problem with windowless solid counting is contami-

Comparison of Non-flow Counting Methods

	Solid[a]		Gas proportional		Ion chamber (~250 cc)		Liquid scintillation (coincidence)[b]		Liquid scintillation (single tube)[c]	
	C^{14}	H^3	C^{14}	H^3	C^{14}	H^3	C^{14}	H^3	C^{14}	H^3
Precision										
Over-all rms σ (%) with samples of 10,000 dpm counted to at least 20,000 counts[d]	3–5	6–10	1.9	1.9	0.75	1	1	2	1	3
Over-all rms σ (%) with 100 dpm and 2 hr total counting time[d]	7–10	not detectable	3.3	3.3	4	12	2	7	3	15
Sensitivity										
Calculated minimum disintegration rate (dpm) for counting precision of 1% in 2 hr[e]	4,000	21,000	275	275	240	1,500	200	1,000	275	1,750
Minimum detectable disintegration rate (dpm) (approximate)[f]	20	200	2[g]	2[g]	8	40	2	10	3	30
Intensity limits										
Maximum countable disintegration rate (dpm)[h]	2×10^7 (proportional) 5×10^5 (G-M)	10^6 1.3×10^6	1.2×10^6	1.2×10^6	3×10^9	2×10^{10}	10^6	5×10^6	10^6	5×10^6
Maximum effective or usable sample	25 mg/cm²	0.7 mg/cm²	¼ of volume[i]	½ of volume	volume of chamber		1 mg to volume of cell (depends on sample)			
Approximate cost[j]	$1,400 (proportional) $ 600 (G-M)		$1,500		$2,000		$6,500–12,000		$2,500–4,500	

[a] Thin window counter with background of 10 cpm and 5% efficiency for C^{14}. Windowless counter with background of 50 cpm and efficiency 2% for tritium. Counts are per square centimeter at infinite thickness.

[b] Efficiency taken as 75% for C^{14} and 20% for H^3. These figures apply only to situations with no quenching by either substitutents or color. Some compounds show such effects strongly (*34*), and efficiency and sensitivity may be zero in such cases.

[c] For single tube counters efficiencies are comparable to coincidence counters, but backgrounds may run from 25 to 200 cpm. Background and efficiency of these counters vary widely, however, and the figures given in this column are only representative. Individual units can be considerably better (or worse). Here background taken as 50 cpm for C^{14} and 100 cpm for tritium.

[d] Actual standard deviation from published results or estimates based on published results, personal experience and communications from other workers.

[e] Counting time divided between sample and background in optimum ratio: $t_s/t_b = (r_s/r_b)^{1/2}$ (*5*).

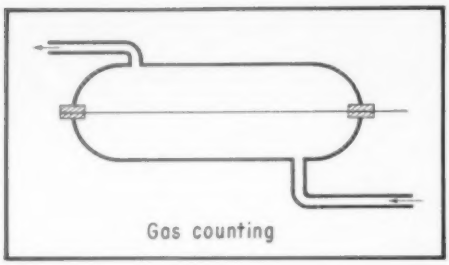
[f] Standard deviation >25%. Total counting time ~4 hr. For counters taken as 4% over background, except 1 cpm over background for C^{14} solid (infinitely thick sample) or liquid scintillation counting. Background taken as follows: gas proportional, 60 cpm (2-in. lead shield). Liquid scintillation (coincidence), 10 for C^{14} and 40 for tritium; single tube, see Footnote c. Ion chambers $(1 \pm 0.1) \times 10^{-16}$ amp; minimum detectable current taken as 2×10^{-17} amp. For C^{14} observed current is $\sim 10^{-16}$ amp/dps (*12*) and for tritium $\sim 3 \times 10^{-17}$ amp/dps (*58*).

[g] With an anticoincidence counter background can be reduced to ~20 cpm for borosilicate glass tubes or 5 cpm or less for quartz or metal tubes; with 5 cpm background minimum detectable activity is ~0.5 dpm.

[h] For scalers that can register 10^6 cpm. A coincidence correction depending on scaler dead time must be applied at large counting rates (*1*, *5*). For a G-M counter, maximum rate is ~25,000 cpm.

[i] Without special purification of CO_2.

[j] Cost for complete equipment from a supply company, ready to use, including one proportional counter (each additional $15–$100, depending on construction) and one ion chamber (each additional $50–$300, depending on size and construction) where applicable. Ion chamber includes $800 for recorder. No vacuum equipment is included in these estimates. All figures include suitable lead shield. For solid counting smaller price is for G-M counter; larger price includes universal scaler and flow counter usable in either G-M or proportional region. For coincidence liquid scintillation counters, larger price includes automatic sample changer.



Gas counting

nation of the counter by volatile samples. Such contamination makes frequent dismantling and cleaning of the counter necessary. Air must be swept out before counting each sample, and shifts in the plateau voltage may occur unless this is done carefully and reproducibly. Furthermore windowless counters are generally more expensive than comparable thin-window counters. For these reasons solid C^{14}-labeled materials are usually counted with thin-window counters even though some loss in sensitivity results.

Even tritiated organic compounds have been counted as solids (*9–11*), but infinite thickness is about 0.7 mg/cm² and efficiencies greater than ~4% have not been achieved (*10*). Windowless counters must be used. It is apparent that such counting of tritiated compounds is most difficult but usable under carefully controlled conditions. For precise work crystallization of the sample must be prevented (*10*), and the technique is not universally applicable except for relatively rough checking of fairly active samples.

Counting efficiencies for C^{14} and S^{35} are generally in the range of 2–50%, depending on type of counter and size of sample. For these nuclides infinite thickness is about 25 mg/cm², and thicker samples do not increase the counting rate (they do, of course, decrease the counting efficiency—counts per milligram of sample). These nuclides are often counted as barium carbonate or barium sulfate, preparation of which involves combustion to carbon dioxide or sulfur trioxide by one of the standard methods (*6, 12–14*). Both nuclides can be counted directly as the deposited organic compound, however, if careful standardization is employed, and in this form the method becomes fairly rapid. In view of the low sensitivity, samples must have relatively high specific activity to produce sufficient counts in a reasonable time.

One can make the absolute efficiency of windowless solid counting approach 50% for C^{14} or S^{35} by using very thin (and therefore small) samples thus minimizing self-absorption and taking advantage of backscattering etc. Maximum counting rates are achieved at infinite thickness, however.

Gas Counting

Many radioactive gases can be counted directly with very great counting efficiency. The sensitivity of the gas counter is essentially 100%, exclusive of the end sections and entrance tubes, and counters are easily designed in which these parts occupy a small proportion of the total volume. Absolute sensitivity of gas counting is the greatest of any of the available methods, but since sample size is limited, other methods can be superior with low specific activities if large samples are available. Typical use of gas proportional counting has been described by several authors (*6, 14–19*) and G-M counting has been similarly employed (*6, 15, 18*). With G-M counting, the total filling pressure must be reproducible, often at considerably less than 1-atm pressure.

It is not possible to count some gases in proportional (or G-M) counters for a variety of reasons. Such gases generally include those that react with counter parts and those that are so easily ionized as to form a conducting path in the counter at a potential smaller than that at which a plateau occurs. Carbon dioxide from wet or dry combustions (*6, 12, 14, 19*) can be used in proportional counters, however, without special purification as long as it constitutes less than ~25% of the total filling. The remainder of the proportional filling usually consists of either P-10 gas (90% Ar, 10% CH_4; Matheson Co., East Rutherford, N. J.) or pure methane. The addition of the extra filling gas is extremely easy and takes less than 1 min per tube, but the counters must then be allowed to stand before counting to ensure thorough mixing of the gaseous components. With techniques now developed, memory effects are generally negligible with either wet or dry combustions. Nickel oxide has been found to be superior to cupric oxide (CuO) as a dry combustion catalyst from this standpoint (*14*).

For tritium, either hydrogen or the lower hydrocarbons can be used as the sample gas. With hydrogen one must use at least 50% methane or P-10 as a filling gas since pure hydrogen ionizes at the voltages needed to count in the proportional region. The Wilzbach combustion method (*20*), which yields a mixture of hydrogen and methane from organic samples, is an extremely useful means of producing tritium samples for proportional counting (*7, 21*) as well as for use with ion chambers as it was originally designed. These methods of producing suitable gases for proportional counting (or ion-chamber measurement) of C^{14} and tritium have the virtue of being a consistent means of producing easily countable samples from nearly any organic compound or water. All samples are treated similarly, both in preparation and in counting, and consistent precision and efficiencies are easily obtained. Potassium perchlorate has also been used as an oxidizing agent under somewhat similar conditions with apparently excellent results (*19*).

Tritium has been counted as water vapor in proportional counters (*18, 22, 23*) but memory effects and relatively poor counting behavior make this a rather questionable procedure. It is much safer to reduce water to hydrogen or to produce a hydrocarbon from it, especially since a number of reagents accomplish either transformation (*24*). Labeled water should be exposed to a minimum of glass at all times because of memory effects.

If partial pressures of carbon dioxide greater than ~¼ atm are needed, one must resort to extensive purification (as in carbon dating with gas proportional counters) (*4*). If only moderate purification of carbon dioxide is needed, gas chromatography using a silicone-on-firebrick column is a simple and efficaceous means of removing most of the common impurities. With such columns there is no cross contamination with $C^{14}O_2$ or CO_2^{18} or even $S^{35}O_2$. As much as 2% sulfur dioxide in P-10 has been successfully counted in the proportional region (a) with a glass counter that has a cathode of a conducting coating of tin oxide and (b) with a stainless-steel counter (*25, 26*).

Gas counters can be made in a number of ways, but for low-level work the material from which the walls are made is important. They should be constructed of metals (*27*) or of selected optical grade quartz (*28*) since borosilicate glasses currently show rather large and varying background effects due to

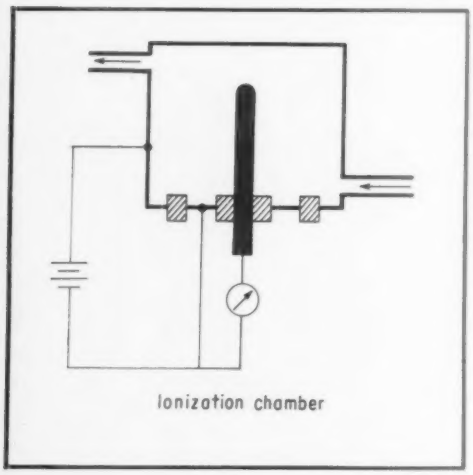
radioactive atoms in the glass (*28*). Within reason, size is not critical with these counters, and some with a volume of several liters have been used successfully.

Ionization Chambers

Ionization chambers have been employed principally to determine activity in gas samples—that is, in samples similar to those used with gas counters—but the chief areas of usefulness of the two methods are somewhat different. The ion chamber can be used with almost any gas that does not react chemically with the chamber walls and it is relatively insensitive to many gases that would be impossible impurities in a counter (for example, air itself). As shown in the table, comparatively large total activities can be determined in an ionization chamber (as much as 1 mc in a sample). It is generally possible to use a larger sample in a chamber than in a gas counter. An excellent general review of the method has been published (*29*).

The ionization chamber is ideal for such applications as measuring activity in (dried) breath as it is exhaled by animals (*30*)—a job that can be done otherwise only by taking aliquots at different times and treating them as separate samples (*31*).

To obtain satisfactory sensitivity with the ionization chamber, one usually converts liquid and solid samples to gases. The methods are generally similar to those used in preparing samples for proportional counting except that purity of gas samples is relatively unimportant. A very simple apparatus can be used to decompose and introduce the carbon dioxide into an ion chamber, since the evolved gas can be simply swept slowly into the evacuated chamber with a carrier gas. The carrier can be air, but other filling gases give somewhat better sensitivity (*29*). Many liquid and solid samples can be counted directly.



Ionization chamber

Although ion chambers have traditionally been cylindrical, spherical models are also being made currently (*32*). These are cheaper than the older types, are available with interchangeable tops of different sizes to fit a standard base and show improved electrical properties since the wall is at a constant distance from the center of the chamber. It is probable that this type of chamber will displace the older type for most applications in the future.

Liquid Scintillation

The relatively recent method of determining many active nuclides, liquid-scintillation counting, applies to all nuclides commonly used in organic chemistry. Under many circumstances it is by far the easiest way to count organic samples: some compounds, however, cannot be counted directly by this means and others only with difficulty. The field has been covered in a book consisting of the papers given at a symposium on the subject at Northwestern University in September, 1957 (*33*) and a recent review (*34*).

With many compounds a very large sample can be used—even up to the volume of the sample cell for compounds such as toluene and xylene (10–50 cm^3 or more, depending on the counter). For this reason the method is capable of detecting much smaller specific activities than any other now used (*35*). With compounds that cannot be used as primary solvents very large samples can often be dissolved and counted. The compound must not show serious quenching effects, however, either because of color (which absorbs the light emitted by the phosphor), or because the compound has a lower activation energy for the absorption of the energy released in the decay than does the phosphor. Compounds that exhibit the absorption effect include many aldehydes, ketones, amines, acyl halides, halocarbons and heterocyclic compounds (*36*). Light absorption by colored compounds is, of course, very serious and makes it impossible to count yellow or red materials except at high dilutions. (The peak of the light output from the common scintillators used for this purpose occurs at about 4,000 A, and any compound that absorbs in that region will show this effect to one extent or another.)

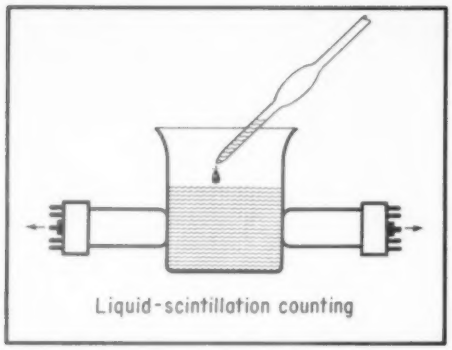
Usually no combustion is needed before counting a sample, and this fact gives the dual advantage of saving considerable time and not destroying the sample (a compelling argument when recovery of a compound is desirable). This feature is also valuable with nuclides having very short half-lives, since one must use a minimum of time for sample preparation (*37*).

One problem with liquid-scintillation counting is that different compounds show different degrees of quenching, and the effect must be checked for each class of compounds in each concentration range (*38*). This is usually done with an internal-standard technique, the sample being counted before and after the standard is added.

Unfortunately the best scintillating solvents are not the best chemical solvents. The most common solvents used in this method are toluene and xylene, sometimes mixed with alcohol to make it possible to dissolve some water or other such compounds. Dioxan with or without other solution components has also been used for this purpose although it is by no means as good a scintillation solvent as is toluene or xylene (*39*). The solubility problem is aggravated by low temperatures at which liquid scintillation counters are usually operated to minimize thermal noise in photomultipliers.

Amino acids, some whole tissues and such gases as carbon dioxide and sulfur dioxide can be dissolved in a scintillator solution containing a quaternary ammonium hydroxide, hyamine (*33, 40, 41*) and counted directly. Another quaternary base, primene, is capable of dissolving stronger acids such as sulfuric and hydrochloric acids in a scintillator solution (*13*). These solutions, although somewhat difficult and tedious to handle, are quite useful, and using primene is probably the best general method of counting S^{35} now available. Some sulfur compounds can, of course, be counted directly in solution.

Another approach to counting samples insoluble in the usual solvents has been to count them as suspensions of finely divided material, usually with a gelling agent to create a stable suspension (*33, 40–45*). Colorless C^{14} com-



Liquid-scintillation counting

pounds (including $BaCO_3$) can be successfully counted this way, and with remarkably small loss in efficiency as compared with solution counting. But great pains must be taken to ensure reproducibility of the sample with regard to particle size and degree of settling. The counting of suspensions of tritiated compounds has also been attempted, but it is extremely difficult to get reproducible results, and the method is hardly satisfactory for tritium at present (*46*).

A method of counting aqueous solutions by scintillation counting has recently appeared (*47*). Small beads of water-insoluble plastic containing a dissolved phosphor are placed in the counting cell and the aqueous solution is then added. Since the C^{14} counting efficiency is only 11.5% except under special conditions, it would probably not be effective to count tritium by such means at present. Somewhat better efficiency has been reported for a number of nuclides with anthracene crystals as the scintillator under similar conditions (*47*).

Another useful feature of liquid scintillation counters is discrimination between C^{14} and tritium. There is a difference of nearly a factor of ten in the average energy of tritium decays and C^{14} decays; the difference is reflected in the light output of the phosphor and therefore in the signal from the photomultiplier. Since discriminator circuits can separate the C^{14} and tritium pulses almost completely, C^{14} and tritium can be counted simultaneously in the same sample (*33*). Other nuclides of reasonably different energies can also be handled in this way. With the gas methods, this problem can only be solved by combustion of the sample and trapping of carbon dioxide and water in the usual way, then conversion of the water to a suitable counting gas (*48*)—a relatively tedious procedure which is not adaptable to a large number of samples.

Gases and Scintillators

An interesting counting method has occluded terphenyl in a solid plastic cell into which a gas or solution can be introduced directly (*49*). Two photomultiplier tubes in coincidence are sealed to the cell and the usual circuitry applied. With a cell cavity of ~30 cm^3 the counting efficiency for C^{14}-labelled carbon dioxide is ~90%; tritium can also be counted in the system (with an unspecified lower efficiency). This method avoids filling gases for the counter and has some attractive possibilities, including possible application to determinations of radioactive gases from gas chromatography columns. Circuitry and mechanical arrangements are not simple, however, and commercial versions of the apparatus are not yet available.

Method and Purpose

Wolfgang and Mackay have given the approximate minimum cost that can be expected with each method (*27*). For a laboratory buying all components ready to use from a nuclear supply company, however, actual costs are likely to be considerably greater than these minima. Our table shows comparative costs on such a basis. Since with different counting methods much of the instrumentation can be interchangeable, costs are not necessarily additive in making several methods available. Ionization-chamber measurements require instrumentation not applicable to counting methods. A certain amount of glass and vacuum equipment is needed for all of the methods except liquid scintillation, however, and even with liquid scintillation it must be available to make the method universally applicable.

Solid counting has only its relative cheapness to recommend it over other methods, being much less sensitive than any other method and allowing a precision that compares unfavorably with the others. Except for rough checking of relatively active samples, it is certainly desirable to displace it with one or more of the other methods. All radionuclides commonly used by organic chemists can be counted as solids, but they are usually better measured in some way as liquids, for example with dip counters or scintillation counters (either liquid or crystal). Some can also be measured as gases in counters or ion chambers.

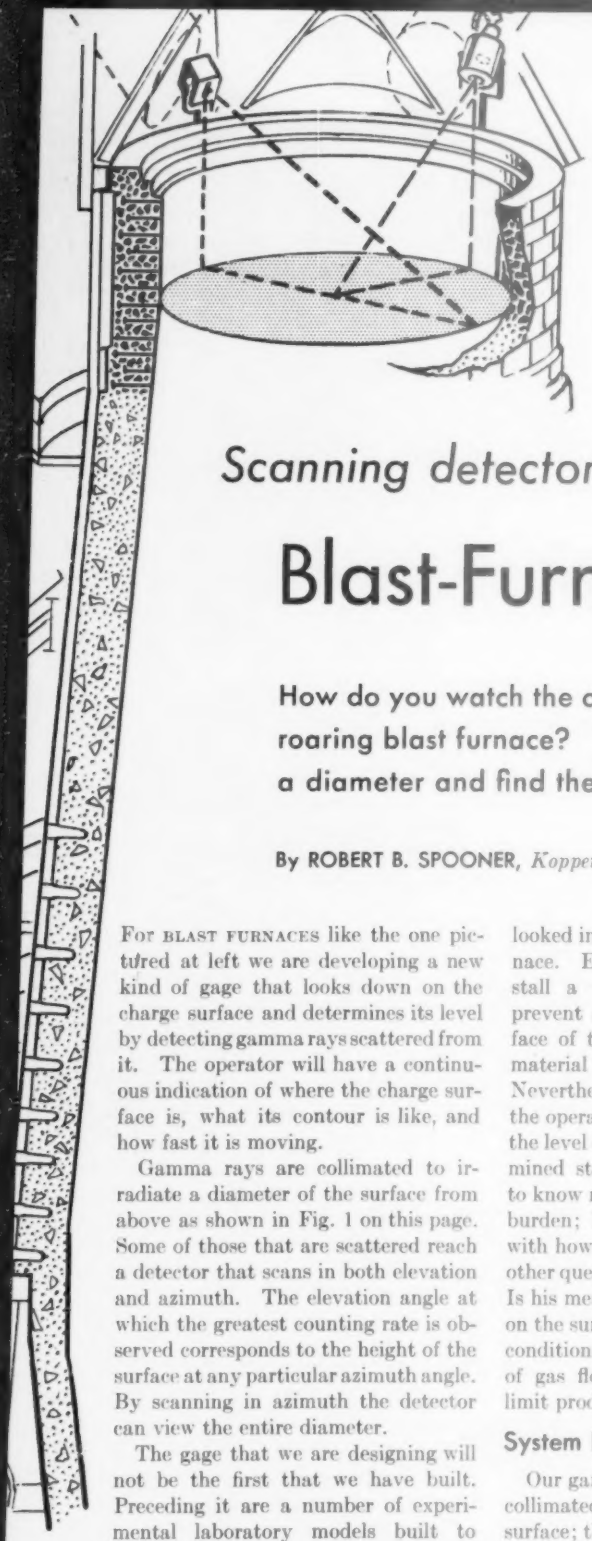
Wolfgang and Mackay have discussed the sensitivities of the various methods of counting static samples from the standpoint of the ultimate sensitivity obtainable under optimum conditions of both instrumentation and sample purity (*27*). It is clear that even under ordinary conditions gas counting is the most sensitive method of determining tritium in a small sample (see table) and is as sensitive as any for C^{14}. The sensitivities for these two nuclides are essentially identical, this being the only method of which this is true. At low counting rates, especially with tritium, gas counting is by far the most precise method available.

As I have already indicated, the ion chamber is extremely useful with many gases that cannot be used in counters and also with very active samples. The precision at moderate disintegration rates is similar to that of gas counting. At low activity levels the ion chamber is less sensitive (on an absolute basis) than a gas counter and is more tedious to use. This aspect could probably be significantly improved only if the background current could be decreased by about a factor of ten. It may be possible to achieve this by placing ion chambers in tandem with opposite polarity on the two chamber walls. The sample would be in only one of the chambers, and background current caused by external radiation should cancel (*50*).

Since it is apparent that relatively few samples per day can be handled by gas counting methods, liquid-scintillation counting has an advantage if large numbers of samples are involved. Sample preparation often consists simply of weighing or pipetting the sample into the counting cell, adding the solvent and placing the cell in the counter; an automatic sample changer can handle as many as 100 samples at a time without further attention. If many similar samples are encountered so that individual internal standardization is not necessary, the liquid-scintillation technique is undoubtedly the easiest and fastest available. Such is often the case in medical and many industrial laboratories where the method has found its greatest use (*51, 52*).

Most commercial liquid scintillation counters now available use circuits with two photomultiplier tubes in coincidence. Although background noise is

(*Continued on page 64*)



Scanning detector makes . . .

Blast-Furnace Gamma Gage

How do you watch the charge in the hot, dusty atmosphere of a roaring blast furnace? This system will direct gamma rays at a diameter and find the height with a scanning detector

By ROBERT B. SPOONER, *Koppers Company, Pittsburgh, Pennsylvania*

For BLAST FURNACES like the one pictured at left we are developing a new kind of gage that looks down on the charge surface and determines its level by detecting gamma rays scattered from it. The operator will have a continuous indication of where the charge surface is, what its contour is like, and how fast it is moving.

Gamma rays are collimated to irradiate a diameter of the surface from above as shown in Fig. 1 on this page. Some of those that are scattered reach a detector that scans in both elevation and azimuth. The elevation angle at which the greatest counting rate is observed corresponds to the height of the surface at any particular azimuth angle. By scanning in azimuth the detector can view the entire diameter.

The gage that we are designing will not be the first that we have built. Preceding it are a number of experimental laboratory models built to demonstrate the principles of operation. We have completed a set of experiments that demonstrate to us the feasibility of our system.

What is Our Problem?

Although blast furnaces have been in use for many years, no one has looked into the top of an operating furnace. Even if it were possible to install a window, dusty gases would prevent any one from seeing the surface of the "burden," as we call the material charged into the furnace. Nevertheless for good process control the operator wants at all times to keep the level of the burden near a predetermined stockline. Moreover he needs to know more than just the level of the burden; he is particularly concerned with how it is moving. And there are other questions he would like answered: Is his measured level the highest point on the surface? Are there nonuniform conditions that may lead to channeling of gas flow or other difficulties that limit production?

System Installation

Our gamma rays come from a source collimated to irradiate a diameter of the surface; the collimated detector can be aimed at any point on the surface. Absolute intensity measurements, which depend on path lengths, scattering materials, surface density and slope, dust content in the gas above the surface and other variables are not necessary. We require only that the system seek the elevation angle of maximum detected radiation. The level is then determined from the geometrical arrangement that achieves this condition.

Thimbles in the upper part of the blast furnace will be so designed that a source ($\sim$150 curies of Co^{60}) and a detector can be inserted from outside the furnace. Components of our system are not subjected to the furnace atmosphere, but are protected and look through windows equivalent to $\sim\frac{1}{8}$-in. of steel such as those we have studied in our preliminary experiments.

Since the operator is not as much interested in absolute height as in how his charge is moving, for the prototype system we have set ± 6 in. as required accuracy under worst conditions and are arranging for one scan across the furnace every 2–5 min. Each scan will take 30–60 sec. These conditions are the results of many design compromises that weigh accuracy and speed of scan against source strength.

The azimuth scan will be automatically programmed and controlled. In elevation the detector will continually seek and track the position of maximum signal as the azimuth scan proceeds. Motions of the detector will provide variable voltages in an analog computer that will give a direct height

reading as a function of position along the furnace diameter.

How It Works

In a form that permits successive or continuous measurements across a diameter of a furnace, the profilimeter appears as shown by Fig. 1. The source is in a collimator that directs radiation in a fan-shaped beam across the specified furnace diameter. Other more complicated beam arrangements can be used for additional information, but our arrangement is the most direct and easy to achieve.

As we made our experimental models, the first and most obvious problem in making this system work was to shield the detector from direct and extraneously scattered gamma rays. To reduce this radiation to a small fraction of the desired scattered radiation required a combination of bulk and shadow shielding. Both source and detector were surrounded by steel bulk shielding ~6 in. thick, and an additional 3 in. of steel shadow shielding was added to each on the side towards the other.

Experimental system. The objectives of our experimental program were (a) to study the basic scattering problem and (b) to determine effects of parameters important to the operation and accuracy of the system.

In our first, scaled-down arrangement, we placed a shielded 10-mc Co^{60} source directly over the surface to be measured. (The original idea for the prototype was to install the source, safely out of reach, in the vertex of the large bell. But occasionally a large bell falls into the furnace under a load of charge. The only thing to do with it is to let it go on through the furnace.) Our shield was a 1-ft cubic box containing steel-brick shielding and a removable collimator section.

The detector, similarly shielded and collimated, was a 1-in.-diameter, 1-in.-thick NaI(Tl) scintillation crystal and a photomultiplier. It could be adjusted in azimuth (ϕ) and elevation (Θ) to scan over a built-up surface. The slot-shaped source collimator gave a narrow irradiated strip on the test surface to define the line along which height measurements could be made. For most of our preliminary experiments the detector collimator was circular, 1 in. in diameter and 5½ in. long.

Our second system, shown by Fig. 2, was a half-size mock-up of the arrangement one finds in a large blast furnace. Source and detector were mounted 6-ft above the floor and measurements could be made across the entire 12-ft diameter of the simulated furnace. For this system a 160-mc Co^{60} source was available and gave reasonable counting rates. It irradiated a strip of the brick surface corresponding to the furnace diameter and extending a short distance up the opposite wall.

Level Measurement

Successful operation of our profilimeter depends on a combination of source and detector collimation coarse enough to produce an acceptable signal and fine enough to ensure the accuracy that we need in the height measurement.

The accuracy with which a height measurement can be made and the ability of the system to follow abrupt changes in level depend on several important system parameters. Chief among them are beam width produced by the source collimator and width of the detector-response curve.

To test the collimation in both of our experimental systems we moved a portable uncollimated G-M detector across the irradiated diameter of the test surface and thereby measured both incident and backscattered radiation. The radiation pattern produced by the source collimator in our half-size mockup is shown in Fig. 3 under several conditions. The solid curves represent three traverses, one directly under the source, one at the wall opposite the source and one halfway between. The curves show gradual widening and decreasing intensity as one moves away from the source. Also shown is the effect of adding a ¼-in. steel screen over the source collimator as must be done to protect the source and collimator from the atmosphere in the furnace. Radiation intensity at the center of the surface is decreased slightly, but the

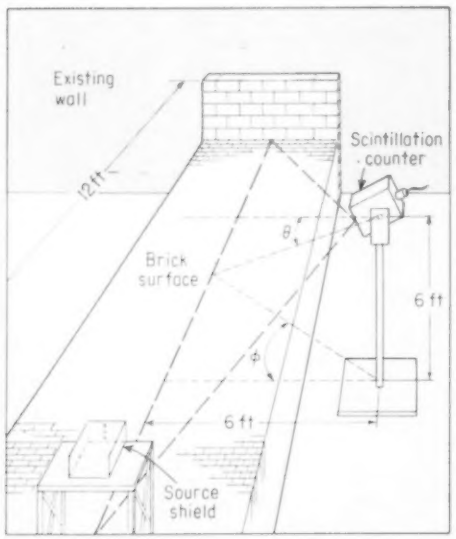


FIG. 2. HALF-SCALE MOCK-UP uses brick surface to represent furnace burden

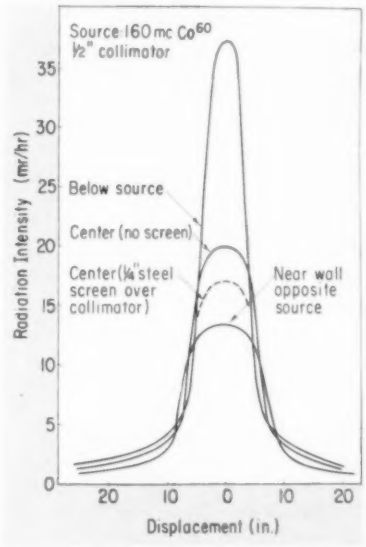


FIG. 3. SOURCE COLLIMATION as tested by moving detector on mock-up surface

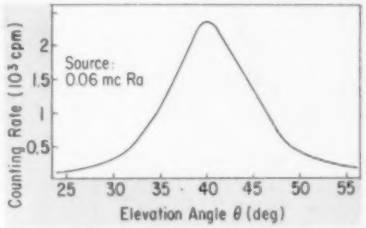


FIG. 4. DETECTOR COLLIMATION measured by viewing 0.06-mc radium source

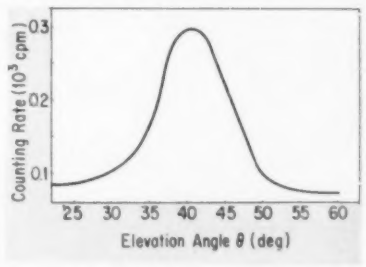


FIG. 5. SOURCE AND DETECTOR produce this pattern when they are used together

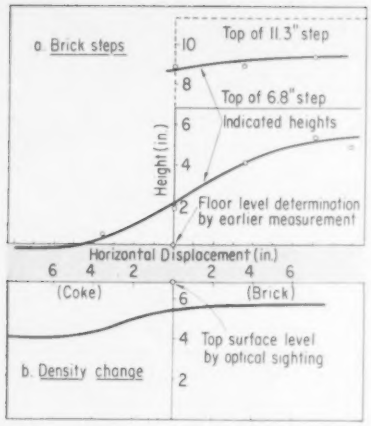


FIG. 6. HEIGHT MEASUREMENTS show step at center of mock-up with fair resolution (a). Level surface made with coke on one side and brick on the other gives small false reading at density change (b)

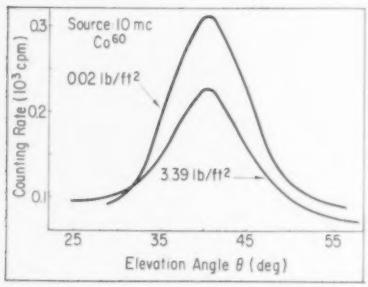


FIG. 7. DUST SIMULATION produces no effect at density typical of operation. Peak is reduced but still well defined with much heavier simulated absorption

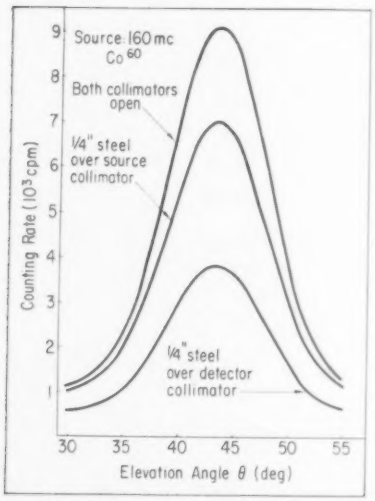

Source 160 mc Co60
Both collimators open
1/4" steel over source collimator
1/4" steel over detector collimator
Counting Rate (10³ cpm)
Elevation Angle θ (deg)

FIG. 8. WINDOW ABSORPTION reduces response when source and detector are protected from corrosive furnace atmosphere by ¼-in.-thick steel plates

width of the pattern is hardly affected.

A typical detector characteristic for our 1-in. collimator is shown by Fig. 4. We got it by placing a small, unshielded 0.06-mc radium source on the test surface and varying the detector elevation angle. The angular width of this characteristic can be assumed to be the same for azimuthal rotation.

When the complete system is operated with source and detector collimation as I have just described them, the detector response is as shown by Fig. 5. This curve shows the detector signal produced by scattered radiation as the detector is rotated through its elevation angle. It is easy to find the angle of peak response from which the level is determined. Because of the narrowness of the source radiation pattern, the width of the detector response is dependent primarily on the width of its own collimation characteristic and has approximately that same value.

Performance Problems

To provide data from which a full-sized prototype system can be designed, we have had to test any limitations that would affect accuracy and speed of response. Other practical environmental factors must be known to reach a suitable design compromise.

Resolution. One of the most important tests of accuracy is the ability of the system to follow abrupt level changes along the diameter that is irradiated. Inherent width of detector response limits ability of the system to resolve two levels separated by a short distance. To test such an ability with a specific combination of collimators, we built a step-function surface as the ultimate in level changes.

The surface was of clay brick, which has about the same bulk density as iron ore. The edge of the step ran along the lines of centers of source and detector of the first model. For the initial height of 6.8 in., a succession of height measurements at different values of the azimuth angle ϕ, and hence distance across the step, gave the lower curve Fig. 6a. As expected, the abrupt change was indicated as spread out over an interval of ~12 in. There was a discrepancy, however. A measurable difference in level appeared to be indicated by the two materials of different bulk density in the step and in the floor. To establish that this difference is largely a bulk-density effect, two additional courses of brick were added, making the step 11.3 in. high. The upper curve shows the indicated brick level raised by a corresponding height.

Bulk-density effect. To obtain more data on the effect of surface material bulk density, an elevated level surface was built, the left half consisting of coke and the right half of brick, simulating iron ore. Coke and iron ore are, respectively, the materials with the smallest and largest bulk densities in a furnace.

We then made level measurements across the material discontinuity. The measured level indication is shown by Fig. 6b and demonstrates the difference between the apparent centers of scattering for the two materials. Also shown is the position of the surface determined by optical sighting. Thus we see that a surface measurement with ~90-deg incident radiation indicates from 1 to 2.5 in. below the true burden surface. According to these measurements, the indicator can be compensated to read ± 0.75 in. Such slight dependence on surface material is unimportant in the measurements that would be made in a blast furnace.

Absorbing atmosphere. One of the critical tests of the profilimeter is its ability to work through the dusty gas above the burden in a blast furnace. Only a layer as dense as the surface of the burden should give an appreciable reflection, and that reflection should permit continued accurate measurements even under varying dust conditions.

The dust content chosen for simulation was that reported as typical of present blast furnace practice. It is based on a figure of 150 lb of dust per ton of hot metal. Typical furnace conditions are

1,410 tons of hot metal/day
84,200 cfm air, 39° F, 1 atm

And in the top of the furnace, where we assume a space of 20 ft between burden and profilimeter, the resulting gas flow rate is

156,000 cfm gas at 330° F, 1.6 psig

The resultant dust in the 20-ft column over 1 ft² of burden surface was determined as 0.0188 lb.

Simulation of this amount of dust, compressed into the space available in the first profilimeter mock-up was accomplished by making six 30 × 60-in. screens of 0.010-in. copper wire

and spacing them 6 in. apart over the test surface. The actual total amount of material provided in this way was 0.0222 lb/ft² of surface.

Measurements of the radiation maximum observed from the 10-mc Co^{60} source are shown by the highest curve in Fig. 7. It is the same as that for no absorbing and scattering medium. We could measure no effect due to the simulated dusty atmosphere. To show an appreciable effect we had to add considerably more material into the radiation beams: three sheets of galvanized steel spaced 1 ft apart. The combination gave 3.39 lb of material per square foot of surface area and a resulting radiation peak as shown in Fig. 7. The peak has been reduced to 0.72 of its original value by the steel sheets.

Protective windows. Another important absorption and scattering problem is created by screens and shields over source and detector, necessary to seal off these parts of the profilimeter from the corrosive and erosive atmosphere of the furnace. Gamma radiation must be able to penetrate them without impairing profilimeter operation.

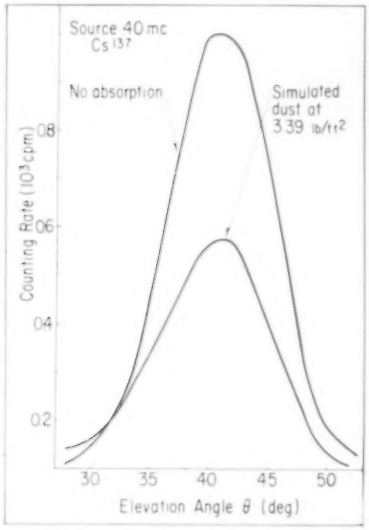


FIG. 9. Cs^{137} SOURCE with photons of lower energy produces results similar to those with Co^{60} shown in Fig. 7

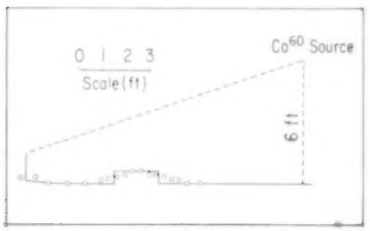


FIG. 10. RESPONSE TO NARROW STEP rounds out corners but shows surfaces to within ⅛-in. in half-scale furnace mock-up

For a 160-mc Co^{60} source in our first experimental arrangement such an effect is shown by Fig. 8. The detector response curve is lowered and slightly broadened by ¼ in. of steel over the source collimator in the primary radiation beam. The same thickness of steel placed, instead, over the detector collimator, and thus in the scattered radiation path, has a considerably greater effect however. Such a thickness, as shown by the lowest curve, is enough to impose some penalties on the profilimeter.

In the half-scale mock-up satisfactory operation was obtained with ¼ in. of steel over the source collimator and ⅛ in. of steel over the detector collimator. With the addition of the detector window the peak was lowered and slightly widened.

Greater screen thickness over the source was chosen primarily for added protection against possible cobalt corrosion-product leakage in the prototype system. The detector window in the blast furnace prototype will probably be a thicker layer of a lighter metal, but of transmission properties close to those of ⅛ in. of steel.

Gamma-ray energy. Use of lower-energy primary gamma rays would simplify shielding and increase scattering. This gain would be offset by greater interaction with extraneous absorbing and scattering materials, however.

Experiments with a 40-mc Cs^{137} source were carried out under conditions similar to some of those of the last section. Figure 9 shows that the results are comparable to those of Fig. 7 and give a ratio between the heavy-absorption peak and that without absorption of 0.58. The decrease is greater than that for Co^{60}. Even the increased surface scattering, expected on the basis of albedo calculations, does not compensate for it.

Furnace Simulation

In view of the effects studied and described in the previous part, a complete furnace could be simulated by the half-size system of Fig. 2. Important parts of the furnace were built up as surfaces and walls. Source and detector system were in proper arrangement and had ¼-in. and ⅛-in. steel covers over their respective collimators. Both brick and coke could be used to make up test surfaces. There was no need to simulate a dusty atmosphere.

In view of the small counting rate, level determinations were made point by point for preselected values of the azimuth angle ϕ. And for each of these we plotted enough of a response curve to give a peak reading for the elevation angle θ and, hence, height.

An example of a step-function test-surface measurement is shown by Fig. 10. Bricks were used to build-up a step 6.6 in. high and 23.4 in. wide. The sharp corners of the surface are smeared-out by the limited resolution of the system. A short distance from the edge of the step the levels are measured accurately however (in this case to within ⅛-in.).

The behavior of the profilimeter near the opposite furnace wall is also of interest and is demonstrated by the figure. At the surface-wall discontinuity the measurement is not discontinuous. Although a small error is introduced, the measurements are continuous and give an apparent surface continuation into the wall.

How Else Can You Do It?

The conventional, nonnuclear way to measure furnace burden is with mechanical stockline recorders, cable supported weights that are lowered until they rest on the surface. But several difficulties affect cable-supported weights. Sometimes one rests in a low part of the surface or buries itself in the charge. Sometimes the cable breaks, and the weight is lost. Since weights are as heavy as 600 lb, replacement is difficult.

Two nuclear methods have already been used, one in Republic Steel's Chicago works and one in Russia in the Dzerzhinskiy Works. Both are beam-interruption gages.

The Republic Steel installation has two sets of source-detector pairs. Four detectors on a vertical line at one side of the furnace face four detectors opposite them; at opposite ends of the diameter perpendicular to the one connecting these sources and detectors are another set, three sources and three detectors. The Russian system is similar, but it uses only two sources and four rows of detectors, two rows viewing each source.

Burnup Experience In EBWR

Fuel elements and control rods show excellent burnup resistance in long-term operation of the Experimental Boiling Water Reactor but control parameters undergo changes adverse to reactor safety

By JOSEPH A. THIE,* *Argonne National Laboratory, Argonne, Illinois*

THE ACCUMULATION of over 8,000 Mwd of core life in EBWR has yielded quite valuable information about fuel-element and control-system performance as a function of burnup. In contrast to the published information on "clean," $t = 0$ reactor systems, very little concrete data are available yet in these areas about the influence of burnup, even though the end-of-life problems may be limiting in reactor design. The experience with EBWR provides one of the first sources of this much-needed data. The lessons learned include:

- The boron-steel control rods have held up so well that the use of hafnium rods now seems an unnecessary expense
- The Zr-U fuel has shown no signs of radiation damage for exposures as high as 5,400 Mwd/tonne (0.58 a/o)
- The decrease in delayed-neutron fraction with burnup is 50% more than expected from simple calculations
- The negative temperature coefficient becomes smaller with burnup and may actually change sign and become positive at 16,000 Mwd
- The latter two effects produce undesirable changes with burnup in reactor safety and dynamic behavior. Although this experience is gained from a boiling-water reactor, much of it will be applicable to other reactors as well.

* PRESENT ADDRESS: McLain Rodger Associates, Downers Grove, Ill.

Control System

Control-system performance during $2\frac{1}{2}$ yr of reactor operation has satisfied design expectations (*1*). Some difficulty in servicing, however, stemmed from "crud" particles falling to the bottom of the vessel.

Especially encouraging is the completely satisfactory performance of the boron-steel rods (see box); this material has proved an adequate substitute for the much more expensive hafnium. The bottom tips of the four boron-steel control rods typically were near the top of the core during operation. In this location they received an estimated irradiation of ϕ (0.0253ev) $t = 5 \times 10^{19}$ n/cm^2, and a fast-flux exposure several times this value. About a tenth of the B^{10} atoms initially present were burned up by this integrated flux.

The initial calibration of the nine rods as a bank (i.e., tips always level) is shown in Fig. 1. Shutdown strength for the rod configuration defined in the box is more than adequate: if desired, up to almost 8 $ additional reactivity could be controlled to give longer

EBWR First-Core Data

The initial fuel loading for EBWR consisted (see figure) of fuel assemblies of two different enrichments (natural and 1.44% enriched) and two fuel-plate thicknesses (0.214 in. and 0.279 in.). The plates were uranium metal alloyed with 5% zirconium and 1.5% niobium and clad with zirconium. The 4-ft-high core contains 9 control-rod positions which take 10-in. X 10-in. cruciforms. The inner five are 0.125-in. hafnium, and the four corner "rods" are 0.25-in. boron steel (2 w/o). Zirconium followers reduce hot spots from flux peaking as the rods are pushed out of the core. The drive is from below the vessel by a carriage and lead screw.

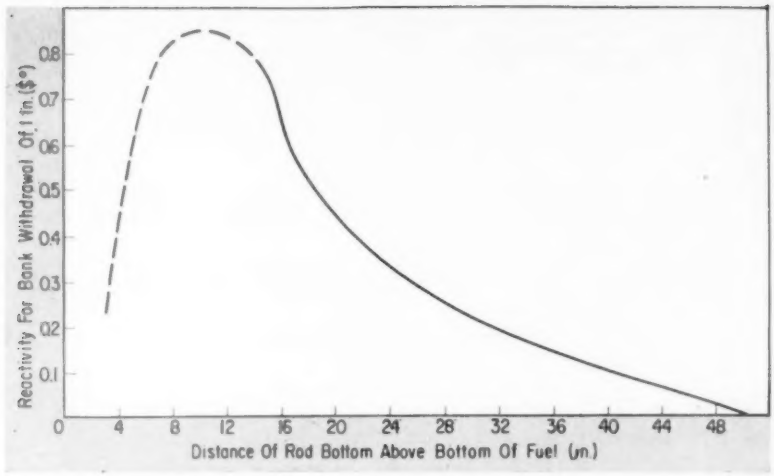


FIG. 1. REACTIVITY CALIBRATION curve for nine-control-rod bank

burnup and/or higher power. ("^{0}" is the value of the dollar in the "clean" core, 1 $\$^0 = 0.717\%$ reactivity for EBWR at 0 Mwd.)

Comparisons of control-rod calibrations at room temperature, at 100 psig (338° F) and at 600 psig (488° F) show that the strength of the rods increase with temperature T, in °F, according to:

$$\text{hot-rod strength} = \text{room-temperature strength}\,[1 + 0.71 \times 10^{-3} \times (T - 70)].$$

This increase results from the increased thermal-migration area at high temperatures that enables the black absorbers to "see" further into the core and capture more neutrons.

A comparison of boron and hafnium as control materials for the central rod gave a worth of 2.07% $\Delta k/k$ for boron vs. 2.02% for hafnium. We might infer from this that in similar reactors (having similar spectra), ⅛-in. hafnium and ¼-in. 2% boron–stainless-steel are very nearly equivalent.

A boric-acid system serves as "backup" control system for EBWR (*2*). It has never been necessary to use this system because of the conservative design and satisfactory performance of the control rods.

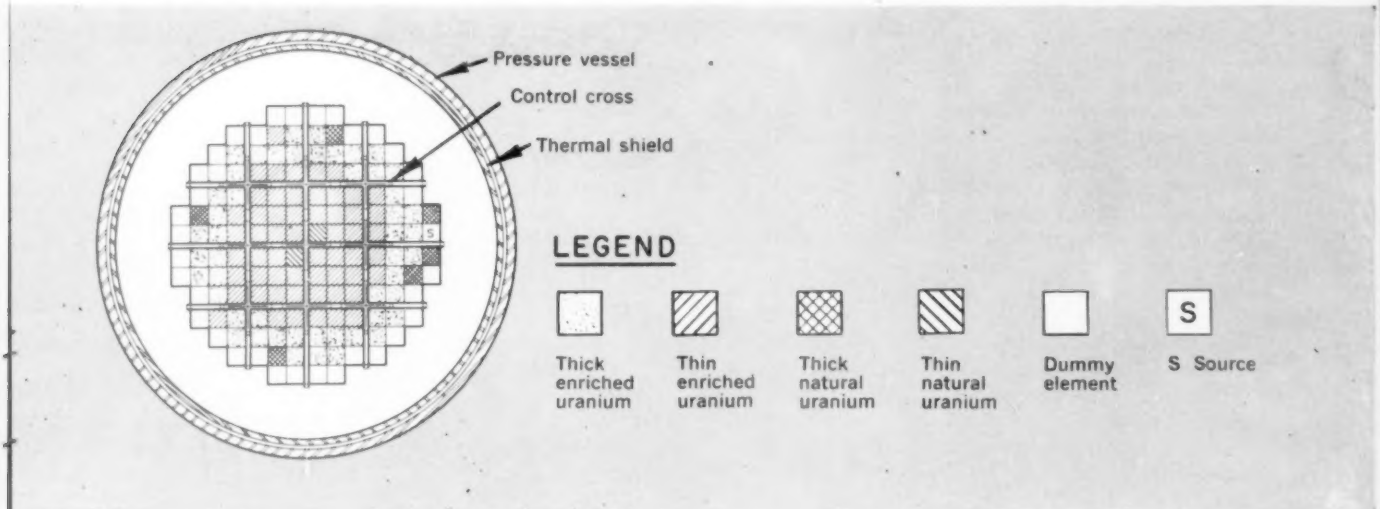
Burnup

The reactor was operated for 8,813 Mwd, giving an average exposure of 1,600 Mwd/tonne of uranium metal. The fuel alloy was uranium metal containing 5% zirconium and 1.5% niobium, clad with zirconium (*1*). Figure 2 shows the reactivity loss due to samarium initially, and long-term effects thereafter. (Slight modifications of the loading shown in the box, such as replacement of the two central natural-uranium elements with enriched uranium, have been "normalized out" of this curve.) Three-group, two-dimensional calculations (*3*) are in reasonable agreement with these data.

With a maximum-to-average power ratio of 3.4 at 20 Mw(th), the peak exposure was 5,400 Mwd/tonne or 0.58 a/o burnup. Examination of fuel having these higher burnups showed no unsatisfactory characteristics had developed due to irradiation so far. However, there was a strongly adhering scale, a few mils thick, coming from the aluminum in the water—this may prove undesirable because of its effects in heat transfer. This scale is mostly Boehmite, $Al_2O_3 \cdot H_2O$, and has been traced to the aluminum boxes in empty fuel locations on the periphery of the core. The problem presumably would be solved by treating the water to minimize its Al content using more corrosion-resistant aluminum alloys, etc.

Dollar Deflation

As plutonium builds up, we expect the value of the dollar to decrease. [A dollar is defined as the percent reactivity that corresponds to the difference between criticality (considering all neutrons) and prompt criticality, (considering only prompt).] The fractions



of delayed neutrons are:

Fissionable nuclide	*Delayed-neutron fraction*
U^{238}	0.0157
U^{235}	0.0064
Pu^{239}	0.0021

Because of Pu^{239}'s small fraction of delayed neutrons as the number of fissions from Pu^{239} increases, the difference between criticality and prompt criticality diminishes.

In reactor operation we observe this effect by noting that a given reactivity change (such as a 1-in. movement of control rods) corresponds to a shorter reactor period, as burnup progresses. Such experiments in EBWR, suitably corrected, give as the burnup coefficient of the dollar value, β_{eff}

$$\frac{1}{\beta^{\circ}_{eff}} \frac{d\beta_{eff}}{d\,(\phi t)} = -\,(2.4 \pm 0.4) \times 10^{-5}\ \mathrm{Mwd^{-1}}$$

where β°_{eff} is 0.00717 at $t = 0$. Thus at the end of the 8813-Mwd irradiation, the dollar value had diminished by 20%. This measured coefficient exceeds simple a priori calculations (*4*) based on theoretical plutonium buildup distributions by about 50%.

Temperature Coefficient

Figure 2 shows that the rate of reactivity loss due to samarium and burnup is different at two different temperatures. We can interpret this temperature dependence as being due to a temperature coefficient that changes with time. The fission resonance in plutonium is responsible for this coefficient becoming less negative as time progresses. When a temperature coefficient is the algebraic sum of many almost canceling positive and negative contributions, it can be rather sensitive to conditions defining its measurement. In EBWR, temperature coefficients are quite sensitive to temperature, control-rod positions and burnup. In fact, widely different values for this coefficient can be had by specifying various reactor conditions. However, the significant set of conditions are those actually encountered by the reactor operators upon startup at various times in core life. Rather than use Fig. 2 as a quantitative measure of burnup effects on temperature coefficient for these conditions, it is preferable to use information based on small changes in control-rod position at criticality at slightly different temperatures, i.e., direct differential determinations of $d\rho/dT$.

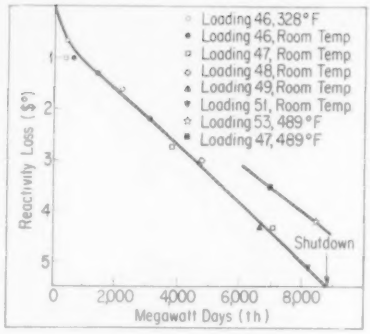


FIG. 2. REACTIVITY LOSS due to samarium and burnup for two temperatures Load numbers refer to slight changes in core configuration from time to time

If $(d\rho/dT)_{avg}$ is defined as

$$\int_{T_0}^{489} (d\rho/dT)\,dT/(489 - T_0),$$

then measurements of this quantity are as follows:

Mwd	$(d\rho/dT)_{avg}$ in \$° per °F, $T_0 = 68°$ F	$T_0 = 328°$ F
0	−0.0084	−0.0129
6,987	−0.0042	
8,150		−0.0075

The coefficient decreases from its initial negative value by a factor of 2. From this it is reasonable to expect the temperature coefficient to reverse its sign after another 8,000 Mwd, i.e., at a total of 16,000 Mwd. (Actually the irradiation of this core stopped at a total of 8,813 Mwd.)

Void Reactivity

Measurements of the reactivity compensated by steam voids at various times during core life showed no significant change directly attributable to burnup. At the nominal power of 20 Mw(th) steam voids represented about 2.7 \$°. Small deviations from this value occurred with changes in control-rod positions (and hence effective core size)—as might be expected. There is no theoretical reason for any significant change in the void coefficient with burnup.

Although a change in void reactivity is at most a "second order" effect, this is not necessarily the case for the void and power distributions (*5,6*). Burnup as well as the control-rod pattern affect this distribution, especially in reactors larger than the EBWR.

Flux-distribution measurements (foils, wires and fission-product activity) have clearly shown the expected effects of voids, control rods and burnup on the flux shape, i.e., depressions in areas of high voids, large burnups or near control rods. Furthermore, a direct measurement of the void distribution (*6*) at 42.7 Mw(th) compared quite favorably with that expected from a priori calculations. We conclude that existing methods for computing voids and fluxes in boiling reactors are quite adequate.

Safety

Some of the factors discussed so far influence reactor safety. We have seen that significant changes in these safety-related factors can take place, even for burnups as low as the 1,600-Mwd/ton average exposure in EBWR. For example, the negative temperature coefficient was reduced by a factor of 2 in this time. Some other effects associated with burnup, also in the direction of less safety, are:

- A buildup of fission products and plutonium
- Decrease in delayed-neutron fraction
- Some loss of fuel-element integrity.

The extent to which safety is modified depends on the individual reactor and the amount of burnup. However, one should not assume that only large changes in a quantity will produce significant changes in safety. For example from the theory of resonant oscillatory tendencies in boiling reactors, one can compute a so-called margin of stability. This may be expressed as the factor by which the reactivity in voids must increase above the operating value before violent spontaneous oscillations occur. The theory (*7*) concludes that this margin decreases directly as β_{eff} decreases.

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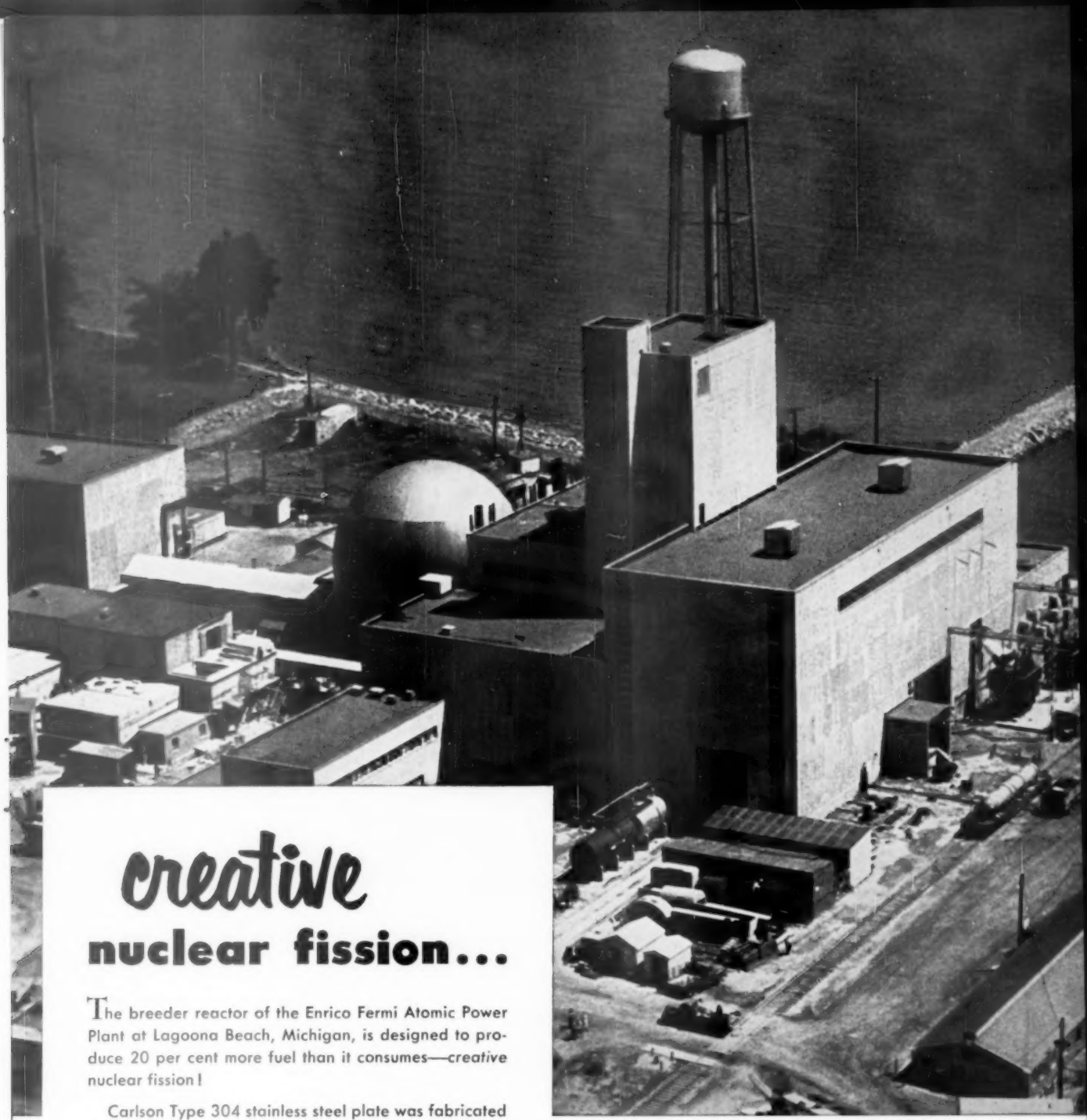

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considerably decreased, sensitivity for C^{14} counting is not greatly affected. Sensitivity for tritium is, however, since background at potentials giving high counting efficiencies is decreased very substantially.

The single-tube scintillation counter is quite satisfactory for counting C^{14} as indicated in the table. A single tube counter is usable for tritium also, but only if each sample is allowed to remain in the counter for 10 min or more before counting to ensure good seating of the sample vial on the photomultiplier tube and allow fluorescence in the vial itself to decay. Furthermore, a very stable high-voltage supply is necessary since the counting rate for tritium changes ~2%/volt in a typical counter of this type (with ~1,400 volts applied to the tube) (*24, 33, 53, 54*).

Proportional counting to determine the activity of components of mixtures as they are eluted from gas chromatography columns has been discussed by Wolfgang and Mackay (*27*). Such determinations are made with ion chambers (*55, 56*), but from the standpoint of sensitivity the proportional counter offers a number of advantages over them. At low activity levels, a large resistor must be used with the vibrating-reed electrometer. The resistor introduces a large time constant into the ion-chamber circuitry, and in such rapid-flow applications as those of gas chromatography this constitutes a serious drawback. At very low levels, the rate-of-charge method must be used, and this cannot be applied to systems in which the activity level is constantly changing. A method involving passing gases, or even solutions, through a plastic tube containing embedded terphenyl and counting the scintillations with a photomultiplier tube has recently been suggested and may well prove to be of value in this field (*57*).

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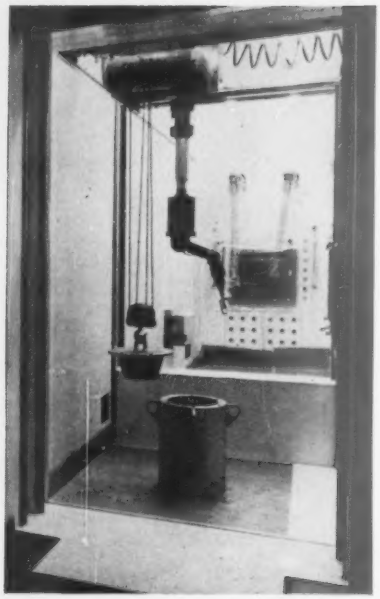

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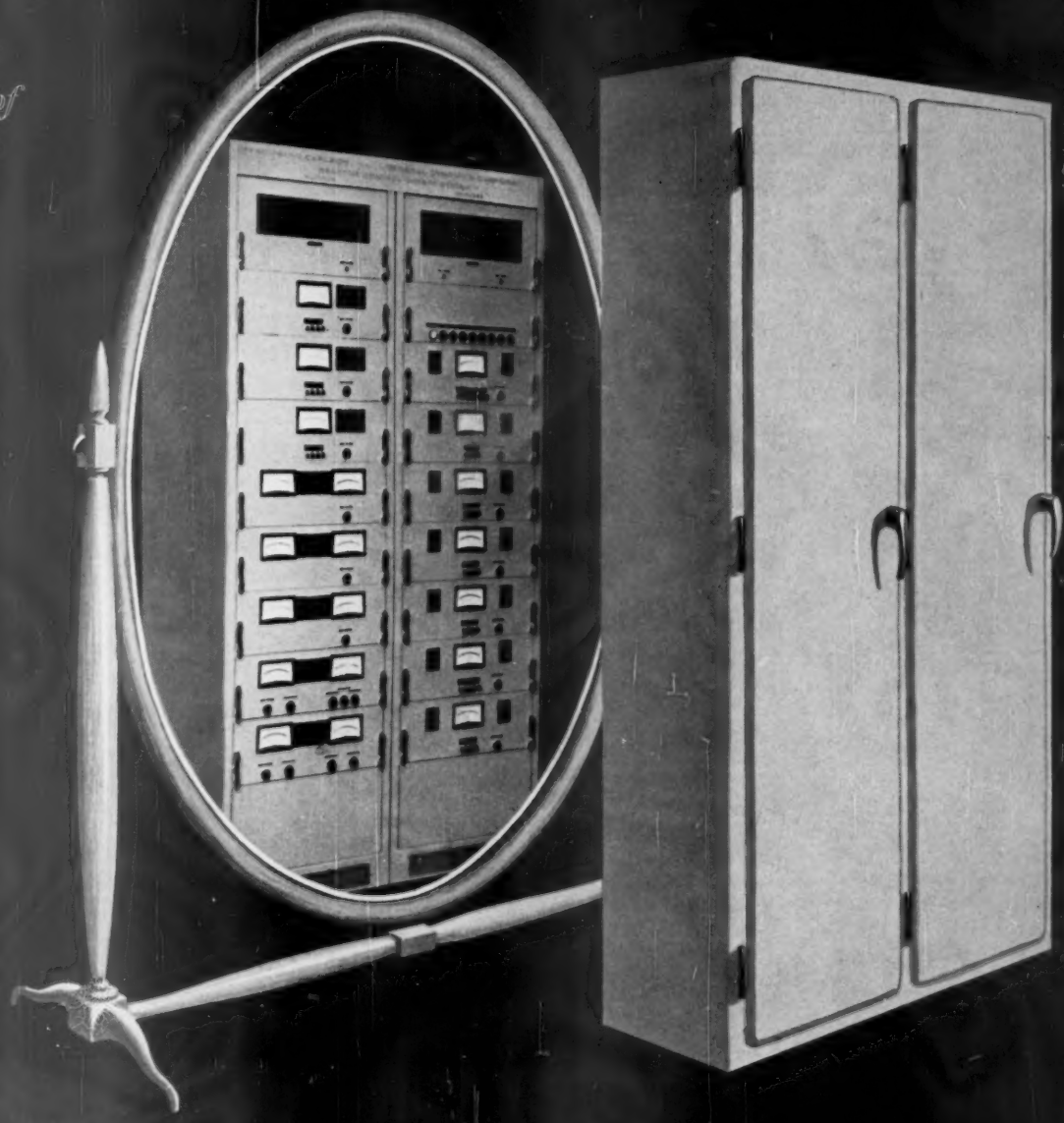

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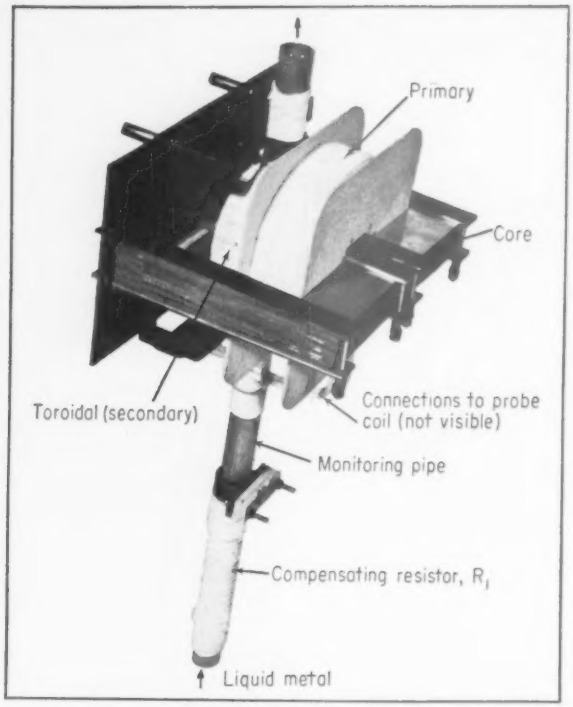

FIG. 1. LIQUID METAL FORMS SECONDARY of transformer as it flows through toroid wrapped around center leg of transformer. Measurement of voltage on probe coil determines resistivity, hence impurity content, of liquid metal

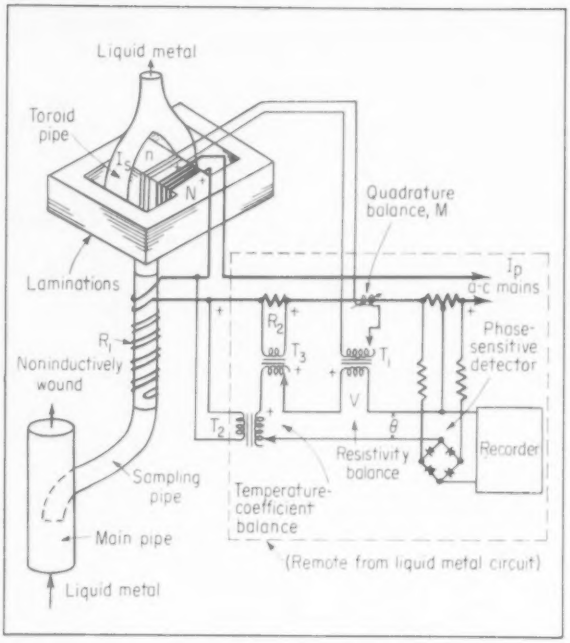

FIG. 2. HOW RHOMETER WORKS: Voltages across resistors R_1 and R_2, in series with N-turn primary, are fed through variable transformers T_2 and T_3 to balance out voltage from probe coil, which is fed in through T_1. This provides measure of resistance of the toroid (liquid metal and pipe in parallel) and hence of the resistivity of the liquid metal. Instrument is sensitive to oxygen concentration changes of 1 ppm

Electrical-Resistivity Meter Monitors Oxygen Content of Liquid Metals

By L. R. BLAKE and A. R. EAMES, *Dounreay Experimental Reactor Establishment United Kingdom Atomic Energy Authority, Thurso, Caithness, Scotland*

The electrical resistivity of liquid metals such as sodium and NaK increases as the impurity concentration goes up. We have used this fact to develop a continuous-reading impurity meter (rhometer) that is sensitive to a change in oxygen impurity of 1 part per million.

When liquid metals are used as reactor coolants the oxygen level must be kept as small as possible. Otherwise this contaminant will not only increase corrosion and wear rate, but will also cause pipe blockage and degrade heat transfer. Until the present time oxygen concentration has been measured by chemical analysis or by a plugging meter that determines the temperature at which oxide precipitates and plugs a perforated plate (*1*). The oxygen level is then found from a solubility curve. Although recent improvements in the plugging meter enable readings to be made at frequent intervals, both methods are essentially discontinuous and depend on oxide precipitation in small passages. The rhometer, on the other hand depends only on resistivity of the

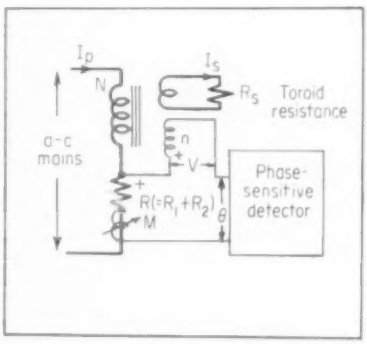

FIG. 3. EQUIVALENT CIRCUIT OF rhometer

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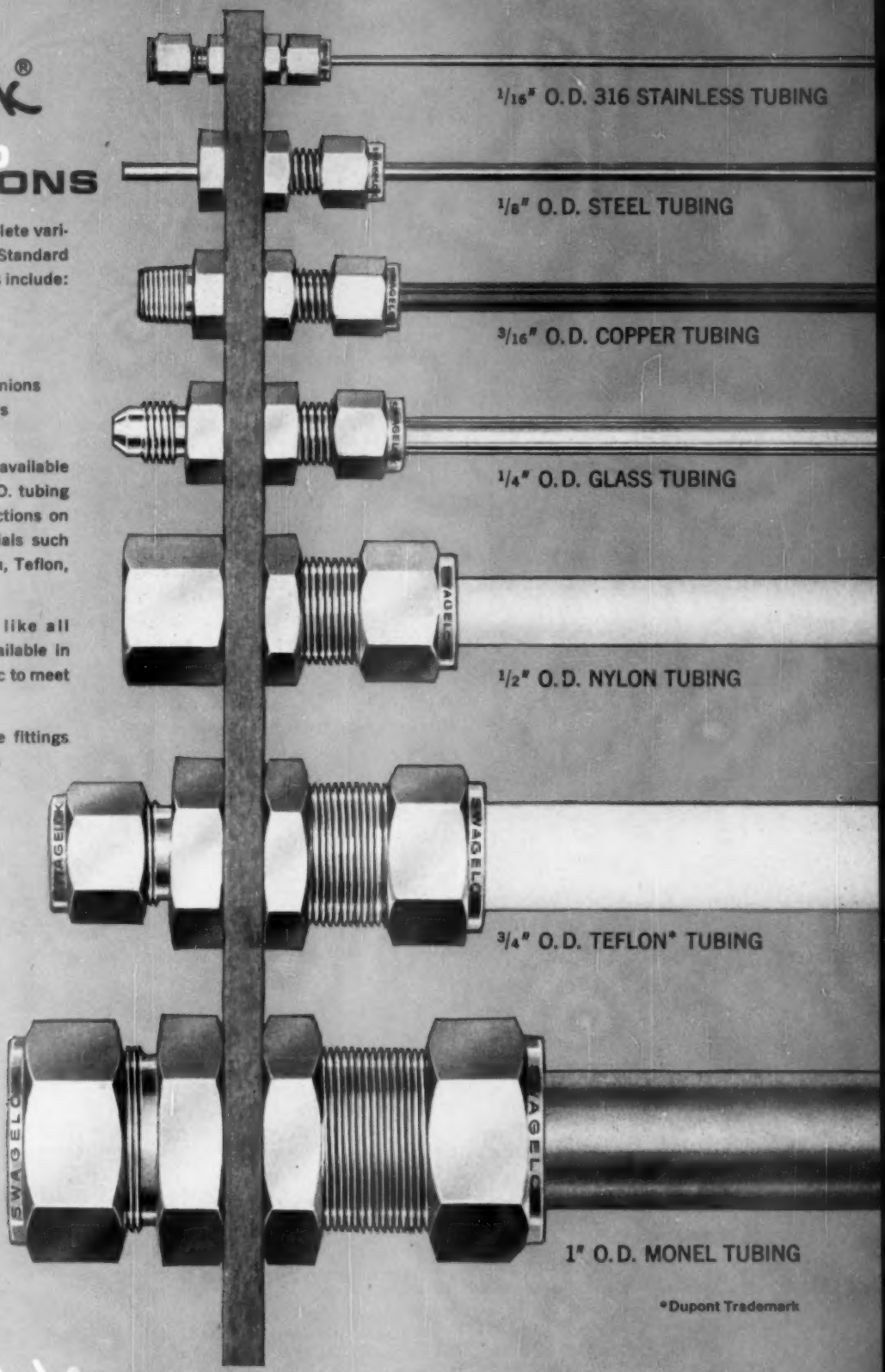

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coolant. Although oxygen is the primary contaminant, our device detects any impurity, including hydrogen and carbon, and also gives a pulse-shaped signal when gas is entrained in the liquid-metal stream.

Rhometers have been installed in primary and secondary circuits in the Dounreay Fast Reactor. Despite the low system temperature (only 150° C) and consequently the small oxygen solubility ($\sim$ 8 ppm), the meters show that cleanup brings the oxygen level below the saturation level.

Operation

A 1-ppm increase in oxygen content increases resistivity in liquid metals by about 1 part in 10^4; thus we want our rhometer to measure resistivity changes as small as that. Accurate measurements are difficult to make, however, because they must be done remotely, which increases the chances for spurious signals, and because a mere 0.04° C temperature variation in the metal also produced a 1-part-in-10^4 change in resistivity. Therefore our main problem in making accurate measurements is to compensate for temperature changes and reduce other spurious signals to less than 1 part in 10^4 (*2*).

In the rhometer, liquid metal circulates through a toroidal pipe that forms the secondary load of a double-loop, magnetic-core transformer with a primary coil of N turns (Figs. 1, 2 and 3). The voltage required to drive the current in the toroid is measured by an unloaded probe coil of n turns. When impurities are introduced into the liquid-metal toroid, the resistance (and resistivity) changes; the voltage through the probe coil for a fixed current in the toroid changes correspondingly. Appropriate balancing measurements (for derivation and detail see footnote *) yield a measure of resistivity change unaffected by other variables.

The resistance R in series with the primary is made of two components: R_1, a high-temperature-coefficient component in close thermal contact with the inlet pipe to the toroid, and R_2, a zero-temperature-coefficient component. By tapping off an appropriate part of the full voltage from each of these two components, one gets two balances and determines both the absolute resistance of the toroid and its temperature coefficient. The temperature-coefficient balance can be made from two balances at different liquid-metal temperatures, or ideally with a slowly oscillating liquid temperature

* In the rhometer, liquid metal is circulated through a toroidal pipe, which forms the secondary load of a transformer having a double-loop magnetic core and a primary coil of N turns. If the magnetizing current is made negligible, the primary current I_p and secondary current I_s in the toroid are related by $I_p = I_s/N$. The voltage V_s, required to drive the current I_s in the toroid, is measured by means of an unloaded "probe coil" of n turns; its voltage is $V = V_s n$. The resistance of the toroid (sodium and pipe in parallel) is $R_s = V_s/I_s = V/nN\,I_p$. If a resistance R is connected in series with the primary coil, such that at balance $V = RI_p$, then $R_s = R/nN$. Adjustment of R or n can provide the balance.

Advantages of Rhometer

- The instrument described in the accompanying article has stability between 1 part in 10^4 and 1 part in 10^5 without stabilizing voltage or frequency supply.
- It is simply, rugged and reliable; monitoring sodium pipe has $1\frac{1}{2}$–$1\frac{1}{2}$-in. bore and normal wall thickness.
- Balance controls can be placed any distance from the toroid.
- No electrical connections are needed to the liquid-metal pipe; current is induced directly in the liquid metal.
- There are no wetting problems between the liquid metal and the pipe wall.
- Output signal can drive any normal recorder without additional amplification. (In Fig. 1 V is 5–10 volts and V_1 is 50–100 mv for 1% unbalance. Meter-source impedance is $\sim$ 100 ohms).
- To keep the thermal time constant small, R_1 can be made of thin strip or small diameter wire.
- Meter input-power is $\sim$ 50 watts.
- Temperature-coefficient balance is accurate: the temperature coefficient $R = R_1 + R_2$ can be made to within 0.4% of that of the toroid.

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(±1–5° C at about 1-min period). In practice, we change the tapping positions on voltage transformers across n, R_1 and R_2, thereby effectively adjusting n for resistivity balance and R_1 and R_2 together for temperature-coefficient balance.

This balancing scheme has two advantages: first, errors from cable resistances are kept small so that the balance controls can be placed far from the toroidal pipe; second, the voltage across R_2 can be subtracted from that of R_1, and the effective temperature coefficient of $(R_1 + R_2)$ can be greater than that of R_1 alone. This is extremely useful since the most convenient resistance material for R_1 is platinum, which has a smaller temperature coefficient (21×10^{-4} per °C) than does sodium (26×10^{-4} per °C at 200° C).

Transformer T_1 is tapped on its primary side. It can therefore be scaled directly in terms of resistance or resistivity; alternatively the secondary can be tapped and scaled in terms of conductance or conductivity.

The variable mutual inductor M eliminates a large unwanted quadrature component in the output signal caused by circuit inductance (such as leakage reactance between the toroid and the probe coil) and transformer magnetizing reactance. This balance is done essentially once for all time since the phase-sensitive detector makes accurate quadrature balance unnecessary (provided its supply voltage is in phase with the wanted in-phase component of the balance current). This feature is as important as the main purpose of the phase-sensitive detector, which is to convert the a-c signal to d-c, while keeping phase information so that one can tell from the recorder trace whether there is an increase or a decrease of resistivity and impurity from the balance condition.

Experimental Results

Tests on the meter show that we achieved the desired stability of 1 part in 10^4 and temperature-coefficient balance to within 0.4%; in fact we got a short-term stability of nearly 1 part in 10^5. Moreover, we found that the resistivity variation with oxygen content below the saturation level was somewhat higher than expected. With $^{24}/_{76}$ NaK the expression for resistivity was found to be $\rho = 17.5\ (1 + 0.0013\Delta + 0.0001\ W)$ [ρ = resistivity (microhm-in.), $\Delta = T - 200$ (T = temperature of liquid metal in °C) and W = oxygen content (ppm)]. Thus, the rhometer has proved capable of continuously monitoring oxygen content and of detecting changes in oxygen level of the order of 1 ppm.

Figure 4 shows the resistivity and oxygen changes following a change of cold-trap temperature. It will be seen that increase of cold-trap temperature from 120° C to 264° C increased the resistivity by 0.38%; the resistivity dropped back again after the cold-trap temperature had been lowered to 70° C.

(*Continued*)

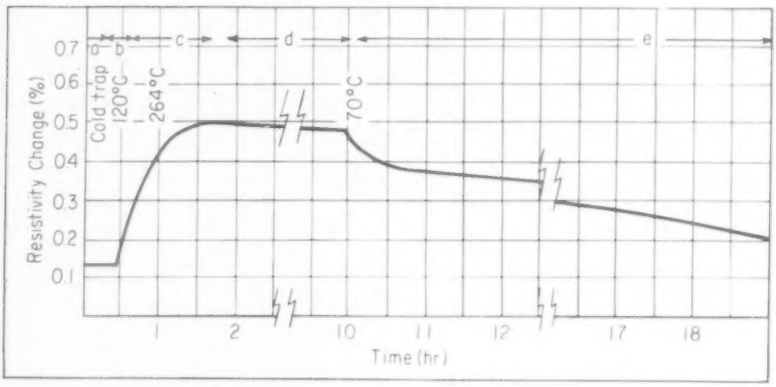
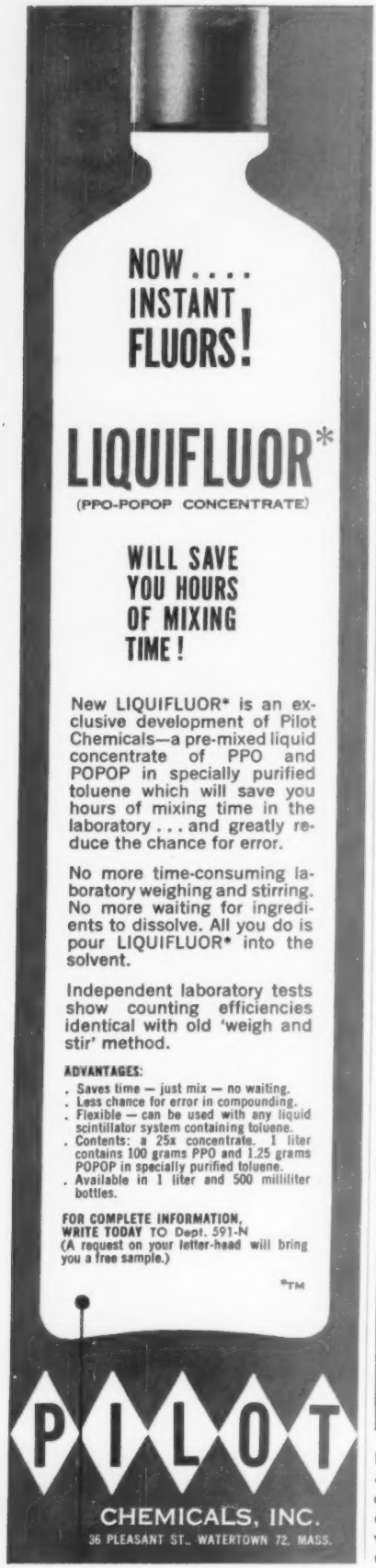


FIG. 4. RESISTIVITY CHANGES reflect change of cold-trap temperature elsewhere in 4-in. circuit of $^{24}/_{76}$ NaK. At (a) cold trap is at 120° C, 10 parts in 10^6 oxygen in NaK by chemical analysis. (b) Cold-trap temperature rising. (c) Cold-trap temperature held at 264° C. Resistivity rises as NaK becomes contaminated with oxygen. (d) Cold trap valved off after resistivity had stopped increasing. (e) Cold trap reinserted and kept at 70° C. Resistivity falls with reduction of oxgen level, eventually, off chart, to 0.09%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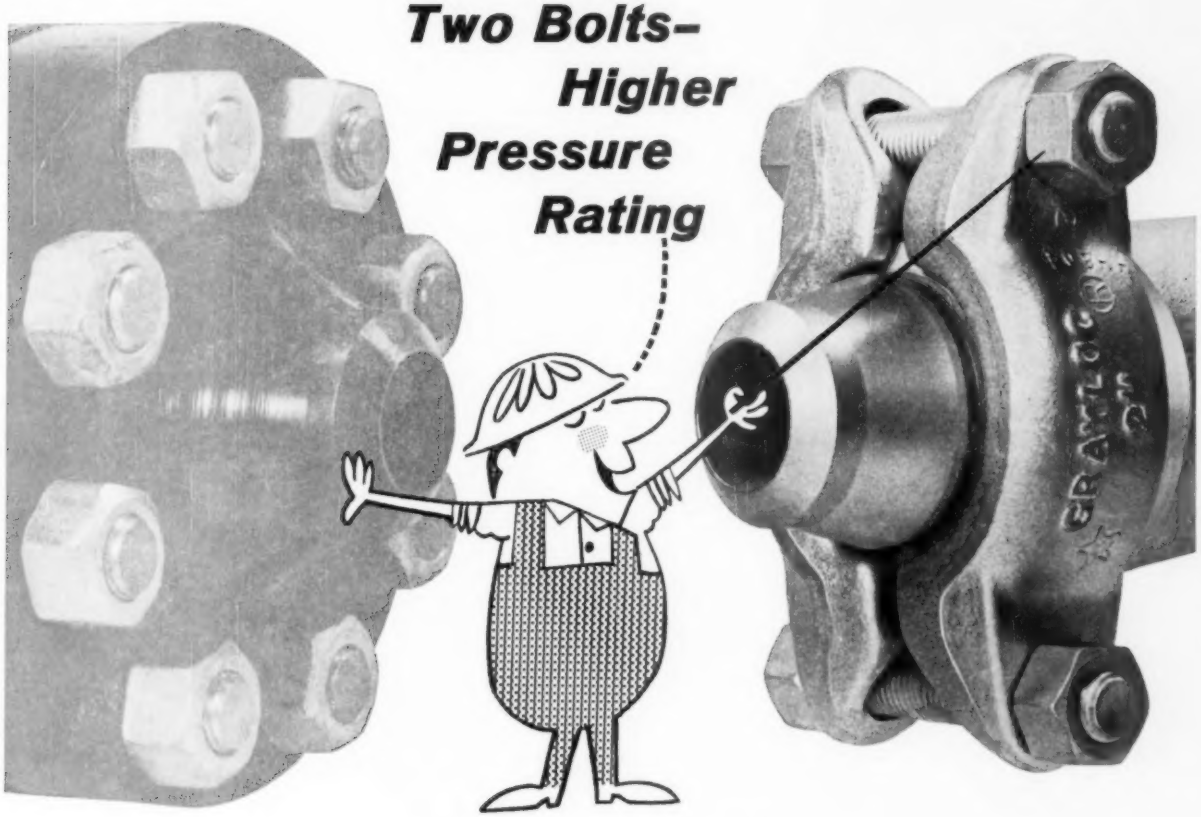

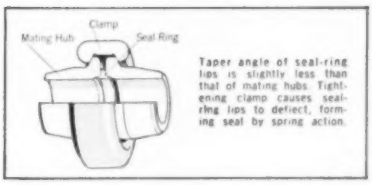
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Rhometer trace tags oxide particles, gas bubbles, gas entrainment

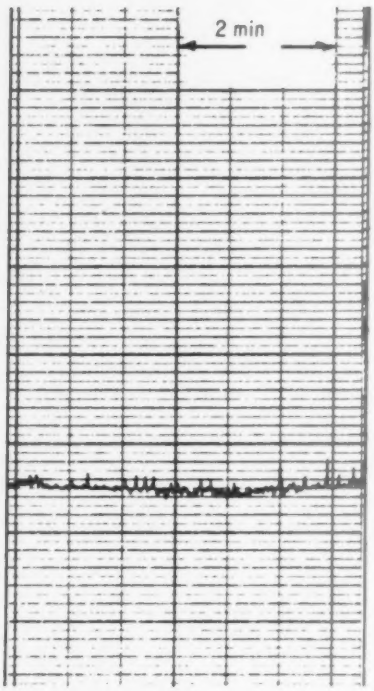

FIG. 5a. SMALL PULSES reflect oxide particles in liquid metal

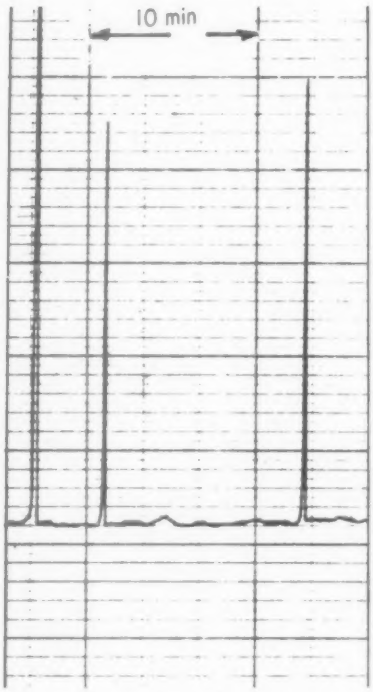

FIG. 5b. LARGE PULSES are caused by gas bubbles passing through toroid

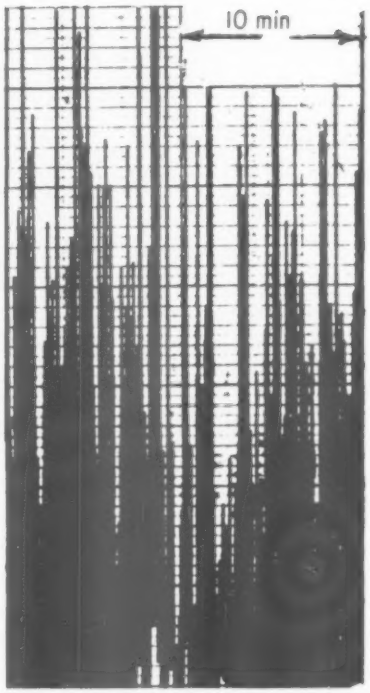

FIG. 5c. MANY PULSES reflect substantial gas entrainment

Inspection of actual recorder chart shows the high meter stability.

Figure 5a shows a typical recorder chart under conditions where the oxygen content is above the saturation level so that oxide particles are present: these can be clearly seen as small pulses on the chart, of pulse length corresponding to the time required for a particle to pass through the meter. Although no experiment has yet been made to determine the sensitivity achievable, it is thought that the characteristic differences between the recorder chart below and above the saturation level should enable the rhometer to act as a precipitation meter. As in the plugging meter, this could be done by lowering the liquid-metal inlet temperature to the rhometer until the pulses appear and indicate that the saturation-temperature has been reached.

Figures 5b and 5c show the rhometer trace with gas bubbles in the liquid metal. From the pulse height can be determined the size of the bubble (a 1% pulse height indicating a bubble of volume equal to 1% of the liquid metal in the toroid), while the width of the pulse corresponds to the time taken for the bubble to pass through the toroidal pipe. Clearly bubbles are readily identified by the large resistivity changes they produce. Temperature compensation to within $\pm 0.01\%$ is achieved over the range 270°–305° C. Remaining variation is due to second-order terms in the temperature/resistivity curves of the platinum compensating resistor, the stainless-steel toroidal pipe and the contained NaK, chiefly the latter. It is likely that the more linear characteristic of pure sodium would further improve the compensated characteristic.

The rhometer has proved extremely valuable in locating the origin of gas entrainment, and has detected gas bubbles in rigs where its presence has previously been unsuspected. It is possible that gas entrainment has been the cause of anomalous heat-transfer results in liquid-metal rigs in the past.

Because of the value of the rhometer in detecting oxide particles and gas bubbles, it is important to be careful in the method of tapping off the by-pass pipe to the rhometer from the main liquid metal circuit. This is best done from a vertical main pipe as indicated in Fig. 1. It is also desirable to mount the toroidal pipe vertically, as shown, to prevent gas or oxide particles being trapped in the toroid.

* * *

The authors are indebted to the Development and Engineering Group Headquarters of the United Kingdom Atomic Energy Authority for permission to publish this paper and to the Windscale Works of the Authority who provided loop facilities for testing the rhometer.

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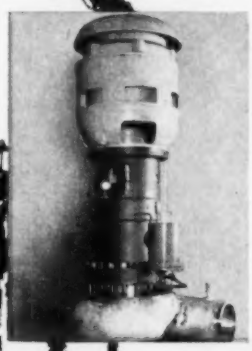

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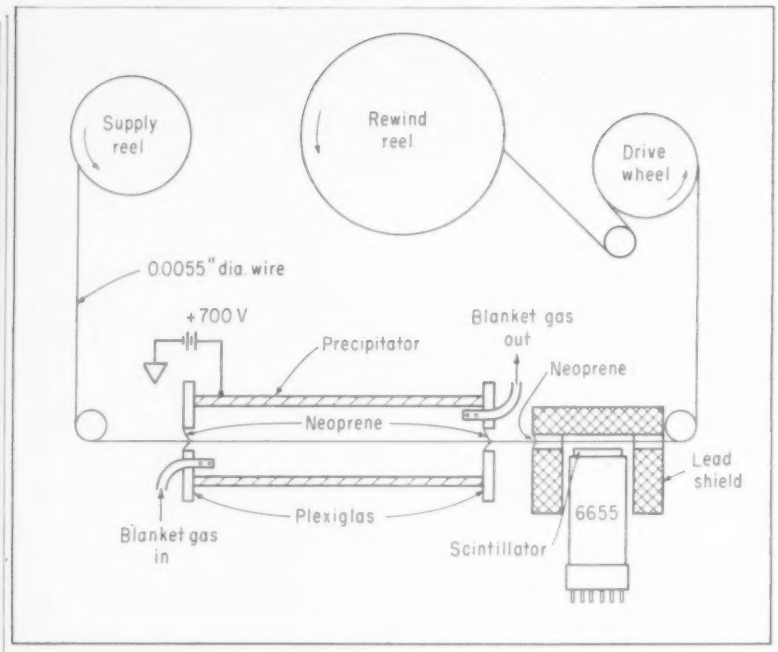

ELECTROSTATIC PRECIPITATION MONITOR collects daughters of fission-product gases on wire, runs wire past scintillation detector to detect fuel failures

Precipitator Monitor Detects Fuel Failures

By A. C. LAPSLEY,* *Savannah River Laboratory, E. I. du Pont de Nemours and Co., Aiken, South Carolina*

One way to detect a reactor fuel failure is to run the off gases through an electrostatic precipitator, collect the daughters produced by decay of fission-product gases and count the decay of the daughters. Such a system has two major advantages. In contrast to liquid monitors, plagued by a background from many neutron-activation products, the gas-precipitation monitor has only the background from Ar^{41}. In contrast to other gas monitors, the precipitation scheme eliminates even the Ar^{41} background since Ar^{41} decays to a stable daughter.

In the belief that the method has much to recommend it, we have built and evaluated a precipitator monitor. Performance has been satisfactory. Since only simple and reliable components are used, few maintenance problems arise. Our experience shows that sensitivity to fission products equals or surpasses those of monitors commonly used in this country.

The British and others have used the precipitator method successfully, but it has been largely ignored in the U. S. Three of the monitors will be installed in the Heavy Water Components Test Reactor at Savannah River, and they are being considered for use in production reactors.

How It Works

In our monitor a gas sample from the reactor passes through a precipitator that consists of a cylindrical tube maintained positive with respect to a wire (see figure). Any gas atom that undergoes beta decay becomes positively charged through the loss of the electron and is attracted to the wire. If the daughter nucleus is a solid, it is absorbed on the wire and any subsequent daughter activity is counted as the wire moves to a shielded detector outside the primary gas stream. Daughters of fission-product krypton and xenon are radioactive solids; that of Ar^{41} is stable. *(Continued)*

* PRESENT ADDRESS: Dept of Nuclear Engineering, University of Virginia, Charlottesville, Virginia.

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CHOICE OF READOUTS: Parallel or serial entry read-out devices, magnetic tape, punched paper tape, electric typewriter, point plotter, printers and strip-chart recorders . . . may all be linked with any of the RIDL line of transistorized pulse height analyzers.

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Four Detector Input is easy, using the Model 30-17 Four Channel Mixer Amplifier for simultaneous operation with RIDL transistorized analyzers. The Model 30-17 provides the logic and electronics to operate 4 detectors simultaneously. Each detector stores into a separate quadrant of the analyzer memory.

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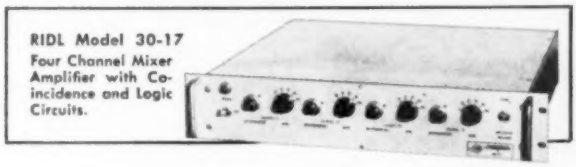
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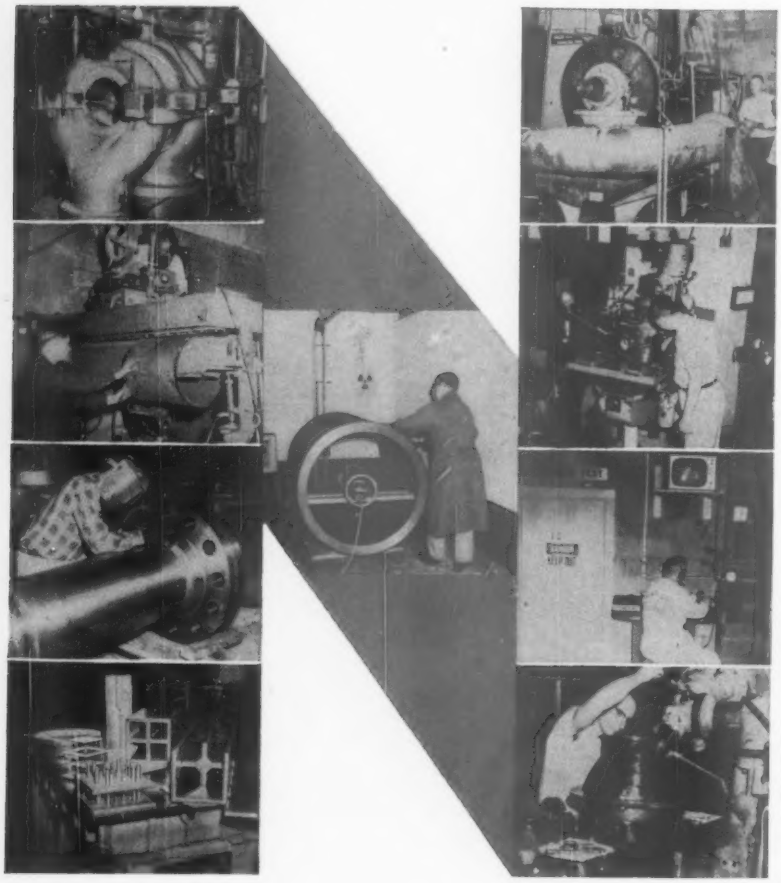

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Precipitator Monitor

This article starts on page 74

Gas circulation. Helium blanket gas moving at 100 cm^3/min enters and leaves through small headers designed to improve the uniformity of flow. Ends of the precipitator are closed with Plexiglas to contain the radioactive gas and provide electrical insulation. Around the wire are gas seals, neoprene washers with tiny holes. The 0.0055-in.-diameter stainless-steel wire moves at 2 in./min. It is used only once and then stored on the rewind reel.

Detection. Five inches beyond the precipitator is a stilbene-crystal beta detector 0.5 mm thick and 1.5 in. in diameter attached to a 6655 photomultiplier. Thinness of the crystal reduces to a minimum its sensitivity to external gamma radiation.

Performance Tests

The precipitator monitor has performed satisfactorily during a six-month evaluation. Separate tests permit us to evaluate background sensitivity, rupture sensitivity and contributions of different nuclides to the response.

Background. The contribution from external gamma background was determined by reversing polarity of the precipitator voltage so as to collect fission-product daughters on the shell rather than the wire. At the time of this test Ar^{41} background was about the same as krypton and xenon counting rates. Reversal of voltage reduced the signal by a factor of 75, indicating that only 1.3% of the signal was due to activity not on the wire.

Rupture. During the rupture of a uranium-oxide fuel element, the counting rate increased by a factor of 160. Since the corresponding increase for gross blanket activity was by a factor of 6, the precipitator technique increased rupture-detection sensitivity by a factor of over 25.

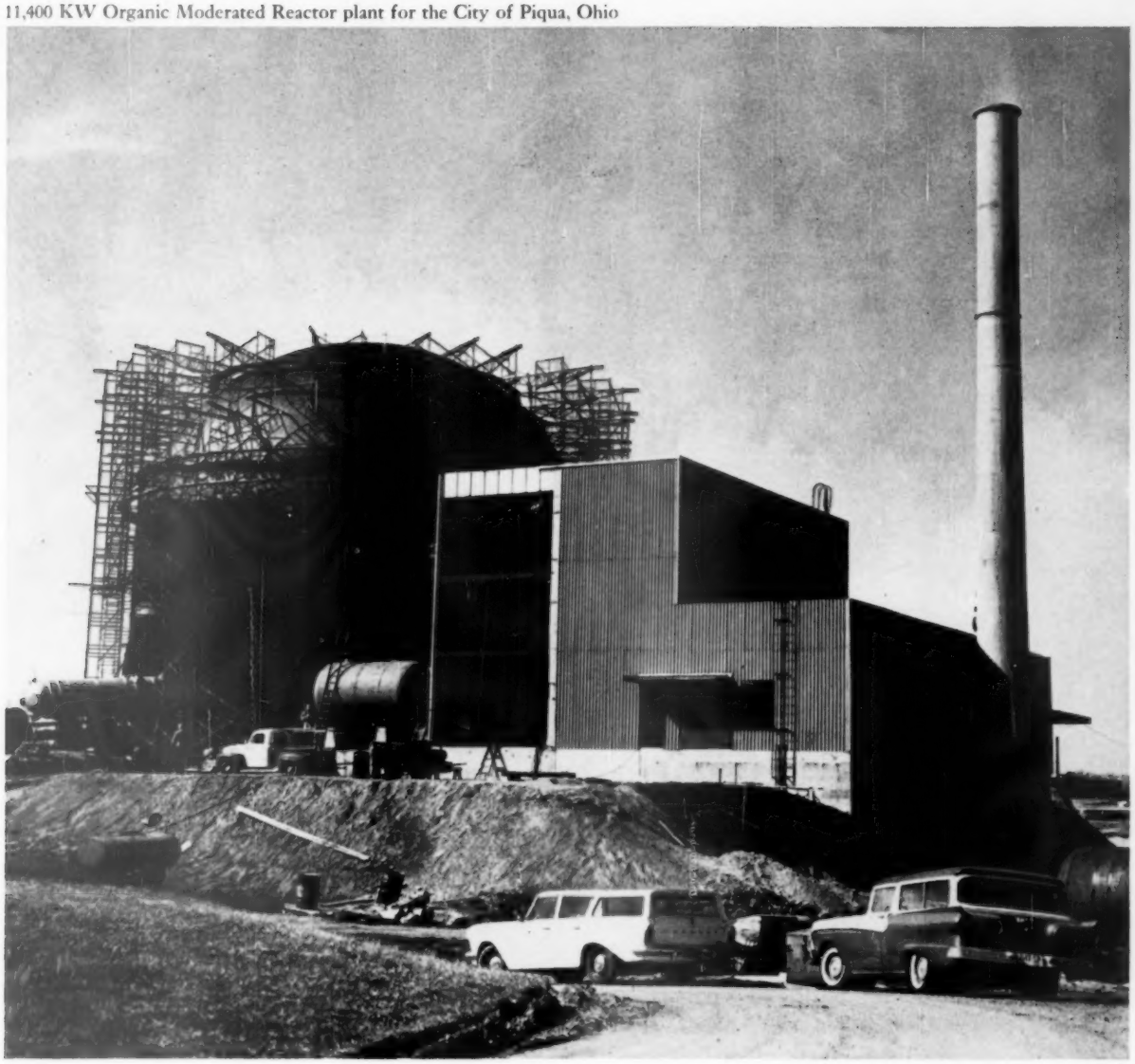
Nuclide identification. By stopping the wire to measure the decay of the precipitated activity, and by stopping the gas flow to measure the decay of the precursor activity we could identify parents and daughters. The precursors were identified as Kr^{88} and Kr^{89} and the precipitants as Rb^{88} and Rb^{89}. No activity that could be attributed to xenon was found.

* * *

The author is indebted to M. H. Goosey of the Savannah River Laboratory, who supplied the discriminator and counting-rate circuit.

The information in this article was developed under contract AT(07-2)-1 with the U. S. AEC.

11,400 KW Organic Moderated Reactor plant for the City of Piqua, Ohio



The Peaceful Atom

Answering the challenge of the Sixties: to double the world's power output in ten years

To meet increased living standards everywhere, the world's power resources must be doubled in the 1960's. In this great expansion the Peaceful Atom will play an ever-increasing role. Atomics International, a leader in developing nuclear power for over 15 years, is already building two of the world's most advanced power stations under AEC programs: the Organic Reactor plant at Piqua, Ohio and the Sodium Reactor plant at Hallam, Nebraska. Another promising concept is the Advanced Epithermal Thorium Reactor project, now being developed by AI for the Southwest Atomic Energy Associates, a group of investor-owned utilities. AI's experience and facilities will play a growing part in meeting the power challenge of the Sixties.

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World Headquarters: Canoga Park, California, U.S.A. Cable Address: ATOMICS. *Other offices:* Washington, D.C., U.S.A.; Geneva, Switzerland. *Affiliated with:* INTERATOM, Bensberg/Cologne, Federal Republic of Germany and DYNATOM, Paris, France

OMRE to Eliminate Corrosion-Product Clogging

Atomics International scientists are confident that they can completely eliminate coolant-channel clogging from deposition of film on fuel-element surfaces that has cropped up in OMRE (NU Wk, July 28 '60). Their plans include precautions during maintenance and refueling operations to minimize contamination of the organic coolant with oxygen and moisture. A continuous filtering system will be installed to remove any corrosion particles formed before they can deposit on the fuel surfaces.

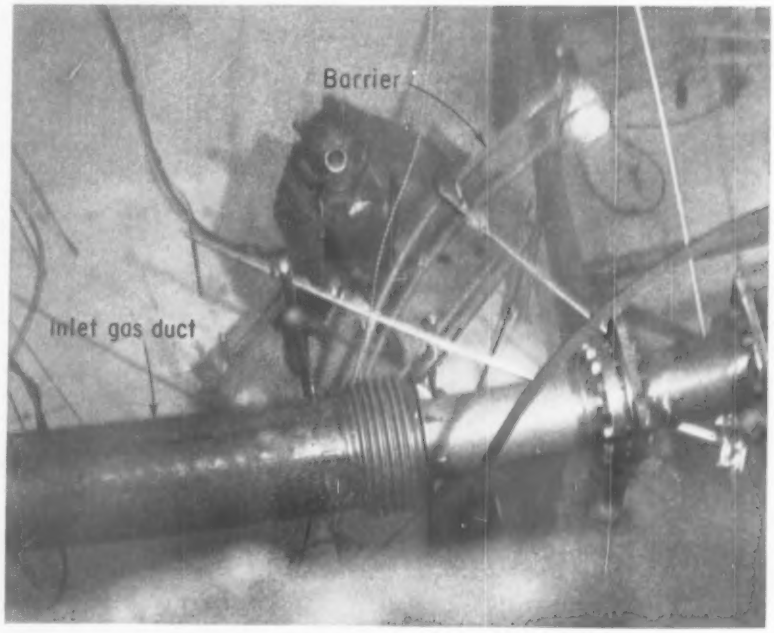
The offending particles seem to be predominately iron percarbide (Fe_3C) and sometimes iron oxide (Fe_3O_4) coated with polymerized organic material. The inorganic nucleii result from corrosion of OMRE's carbon-steel primary system. The presence of these iron compounds is not unexpected, nor is their very large preference for depositing on OMRE's stainless-steel-clad fuel—the concentration of iron in the organic coolant is measured in parts per million while the fuel-surface deposits contain 20% iron. This phenomena has also been observed in water reactors whenever purity control has not been maintained.

As far as AI can piece it together this is what happens: apparently the iron compounds act as catalysts for polymerization of the organic coolant at their surfaces. Hence these particles serve as nucleii around which high-boiling organic compounds deposit. With the passage of the coolant through the coolant channels a large number of these particles impinge on the fuel surfaces. A small fraction are delayed there because of highly localized electrostatic forces or radiation-induced chemical reactions. These particles may then stick permanently to the fuel plates and thus build up deposits in the channels.

AI believes the prime source of the problem is the exposure of the coolant to oxygen and moisture when the vessel is opened for refueling or maintenance. In between these occasions the coolant is kept relatively free of inorganic particulate matter by the distillation bypass that operates continuously to remove high-boiling compounds from the OMRE coolant. AI points out that in a prototype power reactor an inert atmosphere or refueling under liquid would eliminate contamination during open-vessel operations. Moreover in the same core under the conditions when clogging occurred in OMRE's stainless-steel elements, experimental aluminum clad elements (of the type being considered for Piqua and future reactors) showed no signs of deposits. This may be due to the much lower enrichment of the Al elements which makes it more difficult for the beta electrons to escape.

To study the best way to filter out those corrosion products that do get formed, AI is building a special bypass loop integral to OMRE. In this loop it will test the relative effectiveness of a number of different kinds of filters.

Divers Repair GCRE Vessel

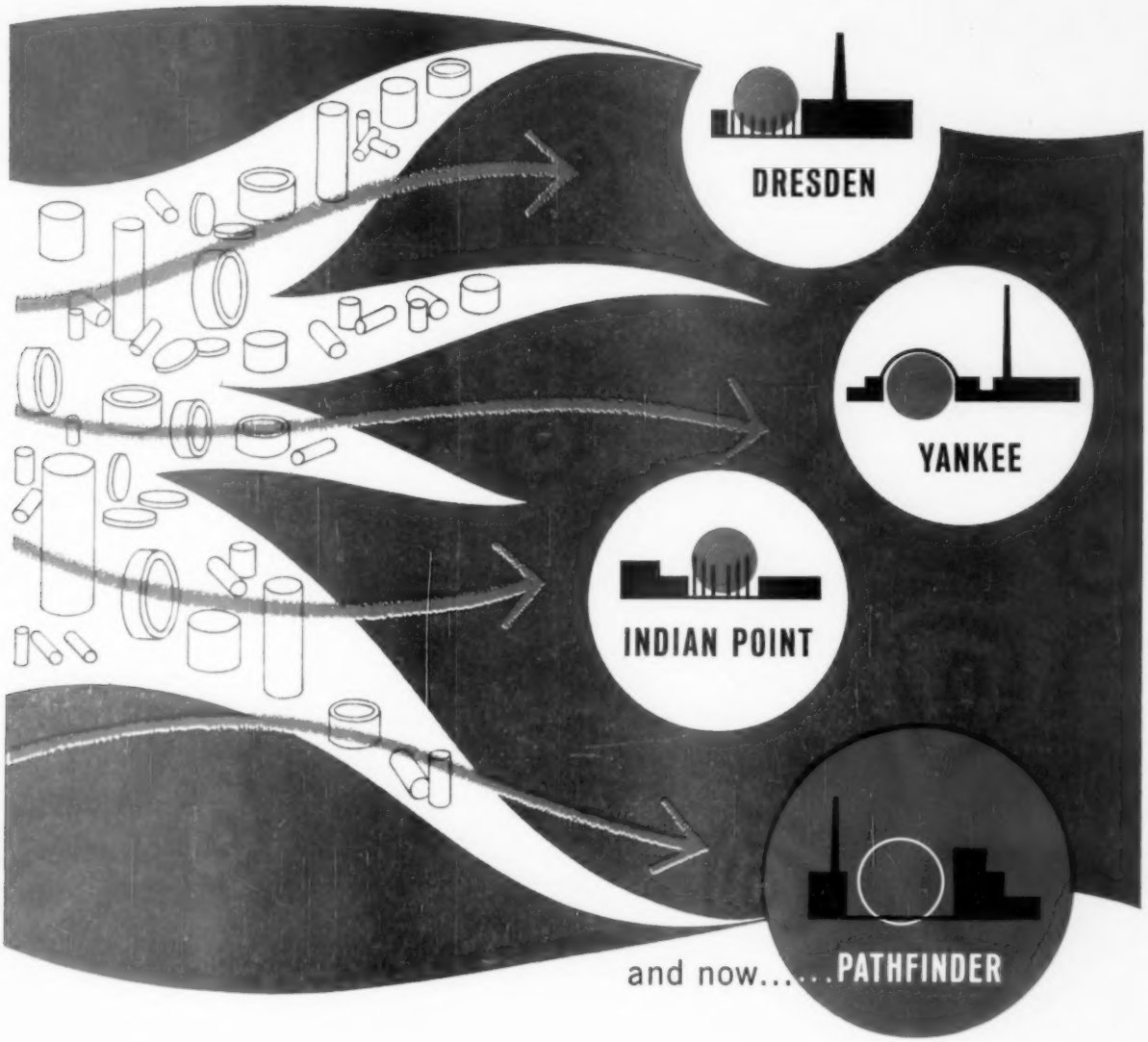


DIVER tightening nut retainer on top part of lower tubesheet flange

When the vessel of the underwater Gas-Cooled Reactor Experiment in Idaho needed repairs recently, Aerojet-General Nucleonics called in professional divers rather than use long-handled tools to make the repairs from the pool surface. The two lines that transmit water to cool the 3-in.-thick tubesheets (they support the core within the vessel) had broken and needed to be fixed. The divers also tightened the 1-in. studs on the vessel's tubesheet flanges, which had worked loose under thermal cycling. Nut retainers were placed over one end of the studs to ease future tightening.

Working behind an underwater barrier that kept them 5 ft from the reactor, the divers tightened the studs and installed the nut retainers by using wrenches with 6-ft handles. One diver had to go beyond the barrier to work for 37 sec less than 1 ft from the reactor to fix a broken coolant line.

Over-all, it took the divers 112 hr to make the repairs. Their bodies were exposed to only ~400 and 600 mr, while their hands received 50% more.



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THE WORLD'S FIRST AND LEADING PRODUCER OF NUCLEAR FUELS

Graphite-Matrix Fuel Bodies

By T. M. BENZIGER and R. K. ROHWER, *University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico*

Graphite as a matrix material offers many desirable nuclear and refractory properties. Its moderating ability coupled with excellent thermal-shock resistance and significant strength to 2,500° C make it unique among high-temperature materials (*1*). Since graphite can be destroyed by combustion and removed as a gas, fuel reprocessing can be simplified (*2, 3*) and the production of large volumes of radioactive liquid waste avoided. And now, with a screw-extrusion process developed at LASL, graphite-matrix fuel of complex shapes can be fabricated.

Major interest in graphite-based elements is for advanced high-temperature gas-cooled-reactor concepts. Of course a corollary of this high-temperature operation is the major problem of retaining the volatile fission products. Aside from Turret (*2*), an active-circuit design in which fission products are allowed to diffuse into the coolant, currently planned reactors such as General Atomic's High-Temperature Gas-Cooled Reactor (*4*), Dragon (*5*) and the several pebble-bed proposals (*6, 7*) envisage the use of impermeable-graphite sheaths, pyrolytic carbon or ceramic coatings to control this problem. While irradiation tests on these fuel bodies have been encouraging, their potential high burnup has yet to be confirmed.

A number of organizations have worked on graphite fuels, among them Atomics International (*8*), Battelle Memorial Institute (*9*), General Atomic (*10*), Los Alamos Scientific Laboratory (*11, 12*) and Oak Ridge National Laboratory (*13*).

Fuel Elements

Most contemporary designs call for graphite-matrix elements in simple tubular form in part because more intricate shapes are not readily fabricated by conventional means. But complex shapes are now attainable by screw extrusion as Fig. 1 shows. The profile need only be biaxially symmetric in cross section and the wall thickness relatively uniform. Dimensional uniformity is excellent; the product does not normally require machining. Total ovality tolerances of less than 0.5%, comparable with commercial fuel-element tubing, can be met. It is possible to extrude and process precision cores in many shapes ready for immediate insertion in metal cladding.

Laminated structures can be fabricated (Fig. 1) that allow concentric zones that can contain fertile or fissile materials at various values of loading. Many obvious possibilities exist in applying extruded elements to radioactive-circuit concepts where their heat-transfer characteristics and temperature capabilities would allow very high specific power ratings.

Production Methods

Most of the procedures for preparing graphite used in laboratory investigations are adapted from industrial processes (*14*). The essential steps are:

1. Preparing a "green" mix from carbonaceous fillers (such as petroleum cokes, carbon blacks and graphite particles) and a binder (such as a coal-tar pitch or a thermosetting resin). Binders must leave a large carbon residue when decomposed by heating.

2. Forming the green mix into the desired shape.

3. Conversion to a hard-baked carbon by heating it slowly to at least 750° C.

4. Sometimes impregnating the baked article with molten pitch and rebaking before graphitization.

5. Conversion into a synthetic graphite by heating to over 2,200° C.

Fuel is incorporated usually as UO_2, when blending the raw materials. During graphitization of the baked stock, the dioxide converts to dicarbide as the temperature rises above about 1,300° C [$UO_2 + 4C$ (matrix carbon) $\rightarrow UC_2 + 2CO$]. Another method is solution-impregnation of a finished shape with uranyl salts. With this technique the salt must be decomposed by careful

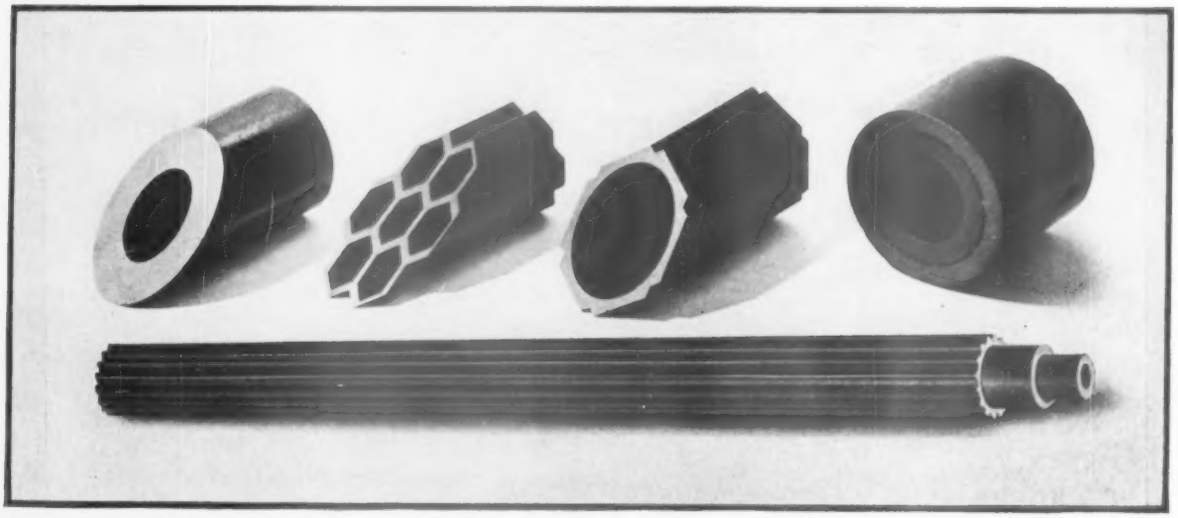
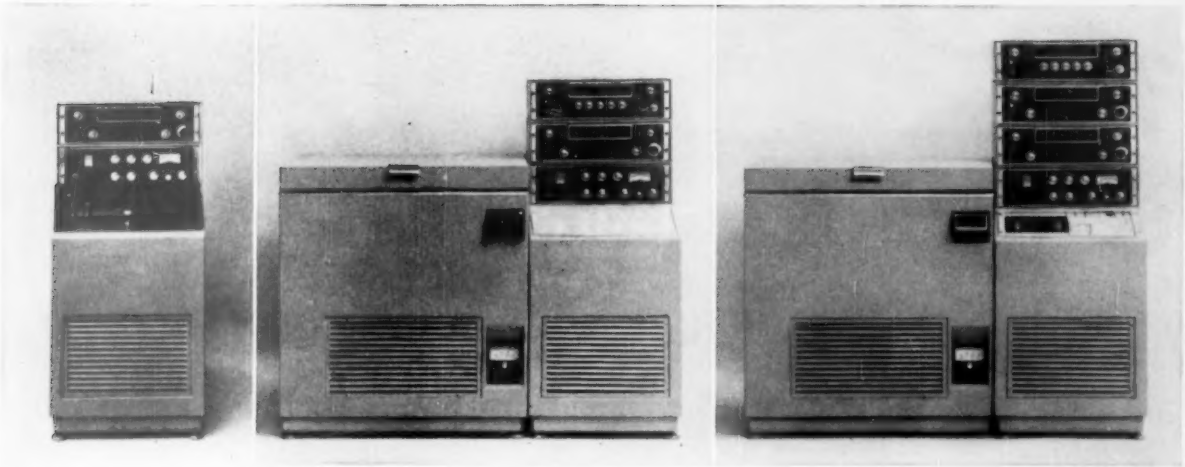


FIG. 1. GRAPHITE SHAPES obtained by screw extrusion. Cross sections at top have outside diameters up to 1¾ in. Laminated assembly at bottom has ¾-in. o. d. Extrusion produces complex shapes more readily than do conventional methods



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heating to a temperature that will produce a stable fuel.

Fabrication

Compression molding, ram extrusion and hot-pressing, processes common in the ceramic and powder-metallurgy industries, are normally used to prepare graphite-base elements. A production method employing a standard plastics-type screw extruder has been developed at LASL (*11*).

Continuous screw extrusion produces extrudate with excellent dimensional and density uniformity at high rates (150 lb/hr with a 2½-in.-dia barrel extruder). Profiles with a major diameter of ¼ to 3 in. have been prepared with wall thicknesses ranging from 1/16 to ⅜ in.; transverse dimensional ratios over 9:1 have been used in strip extrusions. Figure 1 illustrates some structures possible with this process.

In the screw-extrusion process, feed material entering a hopper section is first engaged by a long screw that rotates within a close-fitting heated cylinder. As it is conveyed through the cylinder section by the screw, the material becomes plastic before being forced through the die.

Formulations

The formulation of synthetic graphites has been an art, historically. Most of the present-day materials are adapted from those used in the carbon-brush industry (*15*). The recent interest in graphite in the missile and nuclear fields has led to formulation studies by many groups, prominent ones being Armour Research Foundation (*16*), Battelle (*17*) and divisions of the Los Alamos Scientific Laboratory (*18*).

A number of the known filler-binder systems have been modified for use with a screw extruder; some are listed in the table below. The range in values for a specific formulation shows that a plain graphite can be substantially improved by interposing an impregnation step in processing. As an example, type 2 graphite exhibits a 40% increase in flexural strength and a 20% reduction in resistivity with a single pitch impregnation.

While high-temperature properties of these extruded graphites have not yet been determined, measurements on other admixture-loaded samples (*12*) indicate that most properties show the temperature dependence of ordinary graphite.

Fuel Incorporation

Impregnation by immersing a graphite shape in a uranium-bearing solution suffers from loading limitations—with a normal graphite, a single impregnation using a highly concentrated solution of uranyl nitrate will deposit as fuel ~0.2 gm/cm³ of matrix bulk volume. The amount and distribution of incorporated fuel depends on the accessible matrix porosity, the pore-size distribution and the structure of the graphite.

Admixture loading as UO_2 is normally preferred since a fuel content as high as 1 gm/cm³ can be easily obtained. Large UO_2 particles, such as 100-micron shot, can be used with this method. With particles of this size, most fission fragments are retained within the particle, thus decreasing recoil damage to the graphite matrix and reducing the over-all diffusion of fission products (*20*). Solution impregnation, in contrast, deposits particles of such small size (less than 1 micron) that there is no effective retainment. Matrices containing such small particles are perhaps best suited to active circuits operating at high temperatures. In this case, radiation damage is annealed and many fission-product poisons can escape by volatilization; hence the burnup potential is high. In canned fuels, the required lower operating temperature can restrict annealing. The resultant radiation damage and generation of fission-gas pressures will limit the allowable burnup, thus suggesting the use of large particles in this case.

Incorporation of fuel as UC_2 might seem to be desirable since matrix carbon would not be consumed as in the case of oxide. The carbide, however, is quite reactive and is rapidly destroyed at baking temperatures by reaction with binder decomposition products.

Properties of Screw-Extruded Fuel Bodies

	Type 1	*Type 2*	*Type 3*
Compositions			
Filler	Petroleum coke flours, carbon black to 40%	Graphite flours, carbon black to 20%	Graphite flours, carbon black to 25%
Binder	Coal-tar pitch, 20–23% of mix	Coal-tar pitch, 23–26% of mix	Catalyzed furfuryl resins, 19–23% of mix
Extrusion aid*	Erucic acid, 7% of binder	Erucic acid, 7% of binder	None
Characteristics	Best for very thin sections; requires slow baking rates	Open pore structure; continuous fast baking feasible	Good over-all properties; low accessible porosity
Typical Properties†			
Fuel loading (gm/cm³)	0.2 (10μ nominal)	0.2 (100μ nominal)	0.2 (100μ nominal)
Carbon density (gm/cm³)	1.80–1.86	1.50–1.65	1.75
Flexural strength (psi)	6,000–9,000	2,500–3,500	4,000
Crushing strength (psi)	9,400–16,000	3,000–5,000	9,000
Resistivity (milliohm-cm)	1.75–1.54	1.40–1.10	1.00
Electrical anisotropy (0.750 × 0.080 in. strip)	2.30–2.00	2.04–2.00	
Accessible porosity (% bulk vol., >0.1μ pore dia)	14	24	10

* This extrusion aid, one of several suitable fatty acids, was developed specifically for pitch-binder, screw-extruder mixes (*19*).
† Room-temperature values for optimum formulations; second value, for types 1 and 2, is for stock having a pitch-impregnation step in processing.

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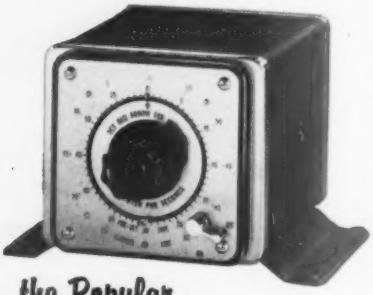

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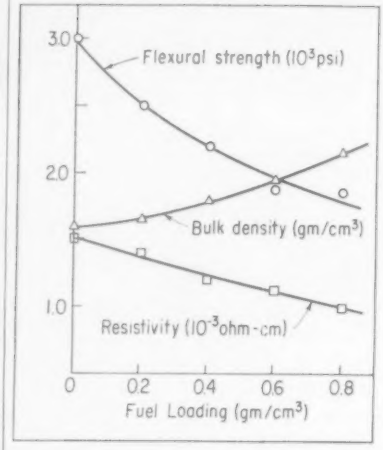

FIG. 2. PROPERTY DEPENDENCE of type 2 graphite (see table) on uranium content; fuel was incorporated as UO_2, 74–104-micron, high-fire sintered shot

The loss of matrix material when using UO_2 is significant but does not seriously influence properties, at least up to loading values of 0.8 gm/cm³ (Fig. 2). Photomicrographs demonstrating this carbon loss are shown in Fig. 3.

Water vapor in air reacts with UC_2 and causes it to revert to an oxide with the evolution of gaseous hydrocarbons. Thus freshly graphitized fuel bodies must be immediately canned or protected with an inert atmosphere. If hydrolysis does occur and operating temperatures cause a repetition of the carbiding cycle, an irreversible deterioration of the matrix will result. A loss in flexural strength as high as 30% has been observed.

UO_2-Bearing Fuel

Baked-carbon fuel bodies that simply contain UO_2 are also of interest since hydrolysis problems are avoided and the high processing cost of graphitization eliminated. Such elements, however, must approach graphite in properties and yet not be exposed to temperatures (~1,300° C) in processing or operation where UC_2 formation becomes significant. Type 2 or 3 material, which can be formulated with large proportions of graphite flour in the filler, develop reasonable properties at moderate baking temperatures (Fig. 4).

Figure 4 also demonstrates the effect of UO_2 particle size. The smaller material does not disturb the packing characteristics of the matrix structure as much and allows a somewhat higher flexural strength. These small particles with their higher chemical reactivity show in Fig. 4, however, the formation at lower temperatures of low-resistivity UC_2.

A major consideration with these bodies is that raw materials be carefully selected for nuclear purity. In the normal carbide-bearing element, a large fraction of the impurities is volatilized at graphitization temperatures. Oxide fuels with their low baking temperatures cannot be rid of contaminants in this fashion. A typical carbon with raw materials not selected for purity will have an ash content of about 3,000 ppm when baked to 1,000° C and approximately 200 ppm when graphitized.

* * *

This work was sponsored by the U. S. Atomic Energy Commission.

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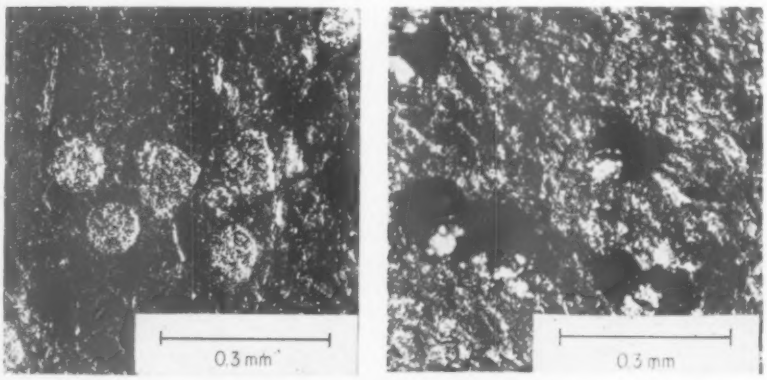

FIG. 3. CARBON CONSUMPTION in conversion of UO_2 to UC_2 during graphitization. At left is baked stock containing 0.8 gm/cm³ of 74–104-micron UO_2 shot. At right, unpolished surface with spherical UC_2 particles and cavities that developed in reaction

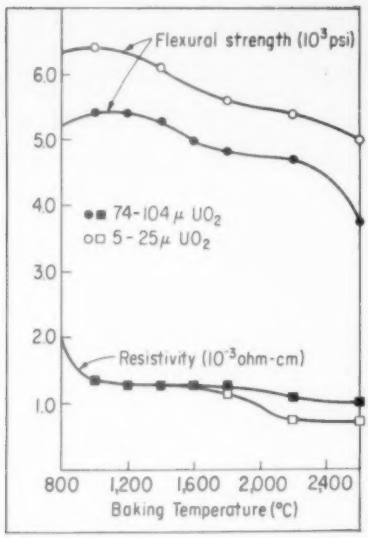

FIG. 4. BAKING-TEMPERATURE effect on properties of type 3 graphite specimens (see table) containing 0.2 gm/cm³ uranium

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Incinerator Reduces Volume of U-Contaminated Paper

By R. C. THORBURN and R. J. CHANDLER
Atomic Power Equipment Department, General Electric Company
San Jose, California

Fuel-fabrication operations in our plant generate about 5,000 ft³ of combustible waste each month. This waste consists of paper and polyethylene bags used to hold UO_2 powder and pellets during and between processing steps and to prevent shop contamination.* Use of the incinerator system described here reduces the cost of handling and disposing of this mildly radioactive waste material.

In each 8-hr shift (1 hr of which is warmup time) this incinerator can burn 1,000 ft³ of waste. During the first 28 weeks of production use, it saved us $82,100 in burning 6,747 cartons (each 2 × 2 × 2.5 ft) of waste that would have cost $108,000 to dispose of without burning. The incinerator and 28-weeks operation cost a total of $25,900 ($12,000 for the system and its operation, $6,000 for tests, $5,200 for filters and $2,700 for labor). Now that we have learned that rapid clogging of the filters is caused by burning items such as plastic, rubber gloves and tape in the incinerator, labor costs will drop at least 30%. We are studying ways to recover some of the < 0.1 wt% uranium in the ashes. Now that the incinerator has proven to be economically successful it has become practical for 60 of our shop workers to wear disposable paper work clothes. This amounts to about 200 ft³ of waste per month.

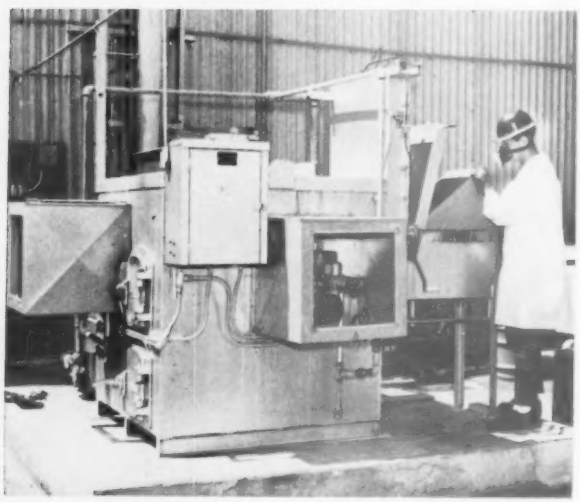
* M. J. Sanderson, P. D. Wright. How General Electric fabricates fuel elements for Dresden, NUCLEONICS **16**, No. 11, 128 (1959).

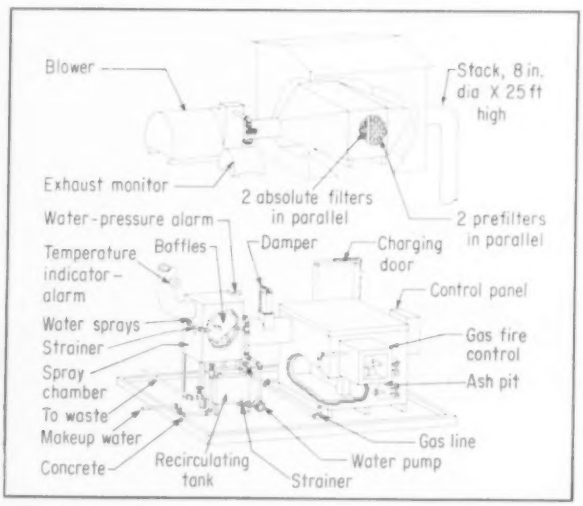
Tests

It took about 8 months to build and test the incinerator. The tests were made to learn the best arrangement of furnace and exhaust system. Uranium-free waste in cartons (2 × 2 × 2.5 ft) of the type used for shop-waste collection was burned in the furnaces being tested; barium oxide served as tracer. The exhaust blower could hold the system at a negative 5-in. pressure while moving 1,500 cfm of air; but most tests were run between 200 and 800 cfm (300–1,200 ft/min air speed in stack).

For three furnace arrangements the tests compared the waste-volume reductions, drafts needed to prevent blowback and excess exit temperature and filter loading rates. We ran the filters to break-through loading to learn pressure drops at which filters should be changed. Preliminary tests showed that for rapid burning to take place the first combustion chamber must be at least 6 in. larger all around than the cartons.

Results. With an incinerator having only a single combustion chamber and a centrifugal fly-ash separator, exit-air temperature at the stack top was 400–600° F; waste volume was reduced no more than 25-fold (allowing for the volume of used filters) and carbon in the smoke plugged the filters so fast that no more than five cartons of waste could be burned between filter changes. By adding a second combustion chamber and a





INCINERATOR REDUCES VOLUME of uranium-contaminated combustible waste by 1.50-fold, cuts disposal costs 75%. It consists of natural-gas-fired furnace (Plibrico-1-100) with three combustion chambers, a 2.2 × 2.2 × 2.7-ft air lock for spill-free charging of waste (on far side of charging door). A water-spray cooler keeps furnace exhaust gases at 300–600° F so filter won't be damaged; blower holds negative pressure in system. Continuous sampler monitors for U that escapes high-temperature absolute filters

spray system to remove fly ash we improved volume reduction to 35-fold and lengthened filter life somewhat, but filter plugging still was excessive. We then tried a three-chamber incinerator with no fly-ash remover since waste combustion was complete, but the exhaust gas was above 1,000° F at all air flows and the filters burned out.

The solution was to use a three-chamber furnace and to cool its exhaust by a circulating water spray. Volume reduction ratios were greater than 150. About 200 boxes of mock waste were burned before the filter clogged enough to need replacement. We prevented blowback by holding 1-in. pressure on the furnace at 600 cfm. About 99% of the BaO stayed in the combustion chambers; the scrubber removed ~1%. Spectographic analyses showed that no Ba escaped the filter and got to the environs. Results were the same when mock waste containing known amounts of natural UO_2 powder were burned.

Operation

At startup each day the furnace takes an hour to heat up before charging begins. Exit gas from the burner is held between 300 and 600° F by adjusting air flow or water circulation in the spray cooler. If the exit gas gets too hot or air flow drops an alarm sounds. An automatic vent maintains an inward flow of air when the charging doors are opened even if the furnace isn't operating. A sampler in the exhaust stack continuously monitors for any uranium emission; because of moisture in the gas the sample stream is passed through an air condenser and then through a sample filter—both filter and condensate are analyzed for uranium. Periodic analyses of vegetation and soil around the incinerator have shown no increase over natural background.

We change filters when pressure drop rises to 2 in.; about 140 boxes of waste are burned before this occurs. After the incinerator cools we spray the ashes on the removable tray with water and shovel them into a 55-gal drum for ultimate disposal. After each burning period the filters in the recirculating scrubber system are cleaned to avoid uranium buildup. The incinerator is mounted on a curbed cement pad, from which drains lead to the liquid-waste treatment area.

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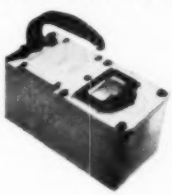

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Health Physicists Push Certification Program

A five-member American Board of Health Physics is now granting certification to health physicists who meet its requirements. The board is essentially autonomous although it has been established by the Health Physics Society and its members are elected by the board of directors of the Health Physics Society. Provision has also been made for the board in the future to contain representatives of other interested groups, who will be chosen by these groups.

Significance of certification can only become clear in the future. Once a certification procedure is defined and set in operation so that a significant number of certified health physicists exists, legislatures, government agencies and industrial companies can, if they like, specify that a certified health physicist must perform certain duties. Presumably adoption of such regulations will depend on the efficacy of the certification procedure, and—on the other side of the coin—the efficacy of certification will probably be greater if demand and need for certified health physicists is great.

The third written examination for certification candidates will be given at the forthcoming Las Vegas meeting of the Health Physics Society. In a sense this will mark the setting into motion of routine certification because until the end of last year candidates could be certified without examination at the discretion of the board. Most of the more than 200 certified health physicists in existence today have been certified without written examination. But three busy years of preparation preceded the first examination—three years of work by committees (that examined the need for certification), a temporary board and an examination panel (that determined what the examinations should cover and how they should be made up and administered).

Board and Panel

The American Board of Health Physics is specifically charged with developing standards and procedures for certification of health physicists, instituting examinations leading to certification and issuing written proof of certification to those who have the required qualifications and successfully complete certification examinations. Until now members have been nominated and elected by the board of directors of the sponsoring society.

The present board has a member whose term expires each year; hereafter all members will be elected for terms of five years. A subsidiary panel of examiners has been established by the American Board of Health Physics. One need not be a member of the parent society to be a member of either the American Board of Health Physics or its panel of examiners.

Program in Motion

The certification program has already produced certifications for 209 health physicists. Of these, 85 were members of a group of 100 "guinea pigs," health physicists whose records were studied for the purpose of setting up the criteria for certification. The 100 were chosen as a cross-section representation of men deemed worthy of certification without question. Other certifications were awarded to men who applied before the end of 1960 and were found by the board to be unquestionably worthy of certification without further examination. About 40% of those applying in 1960 were certified in this manner. And finally there have been 39 candidates at the two examinations that have already been administered by the board.

First step in the direction of a certification program was appointment of Elda E. Anderson, well known Oak Ridge health physicist, as chairman of a committee on certification at the founding of the Health Physics Society in 1956. In November, 1958, a temporary board was appointed. This board selected the 100 guinea pigs and drew up a set of minimal qualifications from a study of their records. The present board was officially established in 1959. Members elected in 1959 were William A. McAdams, chairman, Elda E. Anderson, Lauriston S. Taylor, John S. Laughlin and John W. Healy. Dr. Anderson has now assumed chairmanship of the board, and McAdams, whose term has run out, has been replaced by John W. McCaslin.

Requirements

The person who wants to be a certified health physicist must first satisfy the board that he meets the minimal requirements of academic training, past experience and present involvement in health physics. He may be asked to submit two written reports to show that he is capable of evaluating and reporting the safety of an installation or an operation. Then he is subjected to examinations: a written one prepared by the panel of examiners and an oral one conducted by at least three members of the same panel.

The candidate is expected to have a bachelor's degree in a biological or physical science. If he has no degree, the board can, in exceptional situations, allow him to substitute experience for formal academic training.

(This view of academic training for radiation protection is in some contrast to the view of a group assembled recently under the auspices of the Department of Health, Education and Welfare. A symposium attended by representatives of universities, professional societies, governmental health agencies and others agreed that radiological health specialist training should be primarily a graduate-level function. The meeting was called as a step to reduce a generally recognized acute shortage of trained radiological health specialists. Proceedings of the symposium have been published by the Division of Radiological Health, U. S. Public Health Service, under the title of "University Curricula in Radiological Health.")

In harmony with their intention to emphasize applied aspects of health physics, the board requires at least five years of "responsible professional experience" in the field. The board intends to raise this minimal requirement gradually until it reaches ten years. This does not include training experi-

ence and work as a technician. Graduate work can be substituted for some of this experience, but only up to a maximum of three years. In addition the applicant must be currently engaged during a substantial portion of his time in the practice of health physics or radiological physics.

Examinations

How to examine applicants has been the problem of the panel of examiners under the chairmanship of Frederick P. Cowan of Brookhaven National Laboratory. The 11 members have been selected to cover the country geographically and also to cover the multiplicity of neighboring disciplines that make up the subject matter and responsibilities of health physics.

The panel has written a list of objectives to be achieved in the written examination: examinations should be comprehensive, include problem work, test judgment and attitudes, command respect and emphasize application. Actual preparation of an examination consists in soliciting questions from the panel, compiling a collection of usable questions and then getting approval of the panel as examinations are made up from the collection.

It is the hope of the panel that some day a syllabus will be available to guide applicants in preparation for the examination. In addressing a recent meeting of the New York chapter of the Health Physics Society, Cowan listed the subjects appropriate for such a syllabus. They included fundamentals of radiobiology, dosimetry, physics, statistics, radioactivity and decay, detection methods, air sampling, laboratory facilities, chemical-plant problems, radioactive effluents, hospital problems, X-ray surveillance, shielding, reactor health physics and nuclear safety, and area and site surveys. Until a syllabus is available, it is the hope of at least some of the examiners that examination papers will be released as a guide to applicants' studies. At present the examinations are not given general distribution, but they are given to those who are authorized to take an examination as a help to them in their preparation. Thus copies of Examination 1 were furnished to all those permitted to take Examination 2, and those authorized to take Examination 3 will be permitted to see Examination 2.

Oral examinations have not yet been instituted, but they will be when the examining panel feels it can manage them.

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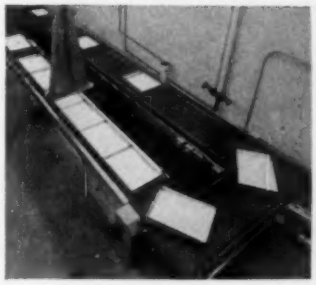
Microorganisms happen to be thousands of times as resistant to nuclear radiation as the more complex organism, Man. When subjected to the penetrating ionizing electron beam of the particle accelerator, however, even the hardiest of bacteria are killed in seconds.



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Electrical Gas Discharge—Competitor to Radiation?

By TORBJORN WESTERMARK, *The Royal Institute of Technology, Stockholm, Sweden*

Electrical gas discharge deserves serious consideration as a potential competitor to large radiation sources for inducing industrial chemical processes. Although Lind (*1*) recognized as early as 1928 the qualitative equivalence of the chemical actions of these two energy sources, there has been little attention to their quantitative relationship.

Radiation and gas discharges both produce molecular ionization and excitation. Radiation involves kinetic energies that are high compared with those of the valence electrons. Radiation processes have been treated theoretically by the Born approximation (*2*). In gas discharges, however, only some electrons have sufficient energy to bring about ionization and excitation. In either case the ions and the excited states are supposed to be the precursors of chemically reactive free radicals, radical ions or free electrons.

The equivalence of these two kinds of actions should to a first approximation be governed by energetic considerations. Since the dose corresponds to the energy absorbed per unit mass, the dose rate is connected with the power. A fraction η (or the radiomimetic efficiency) of the electrical power absorbed in a gas discharge (P) is assumed to act like radiation. The equivalent dose rate is then

$$dD/dt = (P\eta/m)10^5 \text{ rads/sec}$$

where P is expressed in watts and m is the mass of the gas in grams (*3*).

The amount of chemical action, or radiation yield, of ionizing radiation is expressed as G, the number of molecules converted per 100 ev absorbed. Equivalent G-values (G_e) can be obtained for electrical discharges from the yield of chemical products and the electrical energy absorbed (*4*, *5*). Then, η is also given by G_e/G.

The yield G_e is always less than G (and therefore η is less than unity) because of, among other things, heat and light losses in the electrical discharge.

Comparison of Yields

The production of atomic hydrogen provides a comparison of electrical-discharge and radiation yields. Eyring et al. (*6*) have estimated the G-value to be 12–16 (by considering the ionized and excited species formed in hydrogen by radiation) and then successfully interpreted the subsequent chemical reactions caused by the radiation. Some efficiency figures have been published for electrical gas discharges. Converting them to G-values yields figures close to those of Eyring et al. For instance, $G_e = 13$ was obtained from Shaw's microwave data (*7*). The figure agreed roughly with that reported by two earlier investigators. A lower figure was, however, found by McCarthy for his optimum case (*8*)—1 gram-atom/kwh, which would correspond to $G_e = 2.7$ for H-atom formation. Microwaves apparently give "good" figures. Shaw (*9*) compared various types of discharges and favored microwaves for many reasons, e.g., their low dielectric-loss factors and favorable discharge-excitation properties.

The Wilzbach process for labeling organic compounds with tritium (*10*) is also pertinent to our discussion. This process, which in its orthodox form is brought about by the beta-radiation energy of the tritium itself, can be speeded up by several magnitudes by supplying energy from electrical discharges in the gas. The energy requirements for achieving a certain yield can be compared and the η-figures evaluated. The precision is not very good, partly because the power measurements are difficult at present. The table shows a set of η-values calculated from the Wilzbach-Dorfman data (*11*). The primary fixation yield, i.e., the column denoted "impure product," might be of greater interest here. The fact that one η-value is as high as 100% certainly reflects the inaccurate power measurements. (All the values should be regarded as rough figures for the same reason; the results give a magnitude, however.) It is seen that the yield is at least 10% and probably more than 25%.

η Calculated for Tritium Labeling

Substance labeled	*Impure product,* η(%)	*Pure product,* η(%)
p-Dichlorobenzene	100	40
Naphthalene	25	9
Palmitic acid I	12	3
Palmitic acid II	16	5
Average	40	

From work in this laboratory, in particular on microwaves (*4*), η-values for tritium labeling have been deduced (Table 9 of ref. *4*). In general, lower η-figures were obtained; recombination greatly reduced the efficiency. Streaming systems like those of Shaw (*7*) and McCarthy (*8*) would be expected to raise the yields considerably.

McCarthy (*8*) gives yields for the production of NO and NO_2 from N_2 and O_2 and C_2H_2 from CH_4. He states a yield for NO of 0.77 mole/kwh which corresponds to $G_e = 2.1$. Radiation yields (G) differ but are not much larger: e.g., Harteck and Dondes, $G = 6$ (*12*); Restaino, $G = 4$ (*13*); and Henley, $G = 4$ (*14*). For acetylene from methane, McCarthy got 1.2 moles/kwh or $G_e \sim 3.2$. I find no radiation-chemical studies of this process in the literature.

Thus, for many systems, the quantitative equivalence between the action of ionizing radiations and electrical discharges (particularly microwaves) is reasonably well established.

Large-Scale Applications

Michaelis (*15*) has calculated the costs for radiation energy from radioisotope sources and from accelerators. He has also considered electrical discharges and ultraviolet light as possible competitors but without detailed elaboration. Some typical costs calculated by Michaelis are the following: Cs^{137}, \$4.35/kwh; Zr^{95}-Nb^{95}, \$3.65; Co^{60}, \$2.95; and electron-accelerator radiation in the future, \$0.55. These costs apply to 30-kw installations under specified assumptions. From these figures, chemical-production costs can be calculated if G-values are known.

The views presented in the present article might be used to compare costs for particular cases. I will not do this here, but might note that, provided η is about ¼ (which is a justified estimate) and the conversion of mains energy to useful microwave energy is also about ¼ (a reasonable figure), the price per kwh will be higher by a factor of 16 than that for a kwh of mains electrical energy. Even if capital and operating costs are added, gas dis-

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2 Model 600A, 54 ranges

This portable instrument is a battery-operated counterpart of the 610A. Its ranges cover 10 mv to 10 volts, 3 amperes to 10^{-13} ampere, and 10^{4} to 10^{13} ohms full scale. Like the 610A, it has selectable input resistance, a dc to 100 cps bandwidth, and output sufficient to drive recorders directly. Battery life is 500 hours; condition may be checked on the panel meter. **$395.00**

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This instrument is a wide-band dc amplifier, with an extremely high input impedance, high voltage and current sensitivity, and a remote differential input. Its separate input head permits measurements up to 24 feet from the amplifier. The 603 has nine ranges from 2.5 to 1000 mv, with precise gains up to 4000, and a 10-volt output at 10 ma. Bandwidth is dc to 10 kc on the 2.5 mv range, rising to 30 kc on the 1000 mv range. **$750.00**

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This article starts on page 90

charge would probably be competitive with radioactive sources and accelerators. Moreover, no radiation hazards would be present.

The microwave unit might be rather similar to those used for linear accelerators; powers of the order of 10–100 kw are already feasible. Some low-frequency electrical-discharge arrangements are described in the patent literature (*16*). The reduced pressure generally necessary would not be a considerable drawback since pumping work is not large compared with total cost and, moreover, McCarthy (*8*) has found it possible to extend the discharge process to atmospheric pressure if it is initiated at a lower pressure.

The comparisons considered here apply to gas-phase reactions. Discharge-reaction products, however, can be brought into contact with liquids, for example by bubbling the gases through the liquids (*17*).

* * *

The material presented here has been very briefly published in the Swedish language (18). *The author is grateful to Mr. H. Lindroth of this Division and to Mr. B. Enander of the Microwave Division of this Institute for valuable discussions.*

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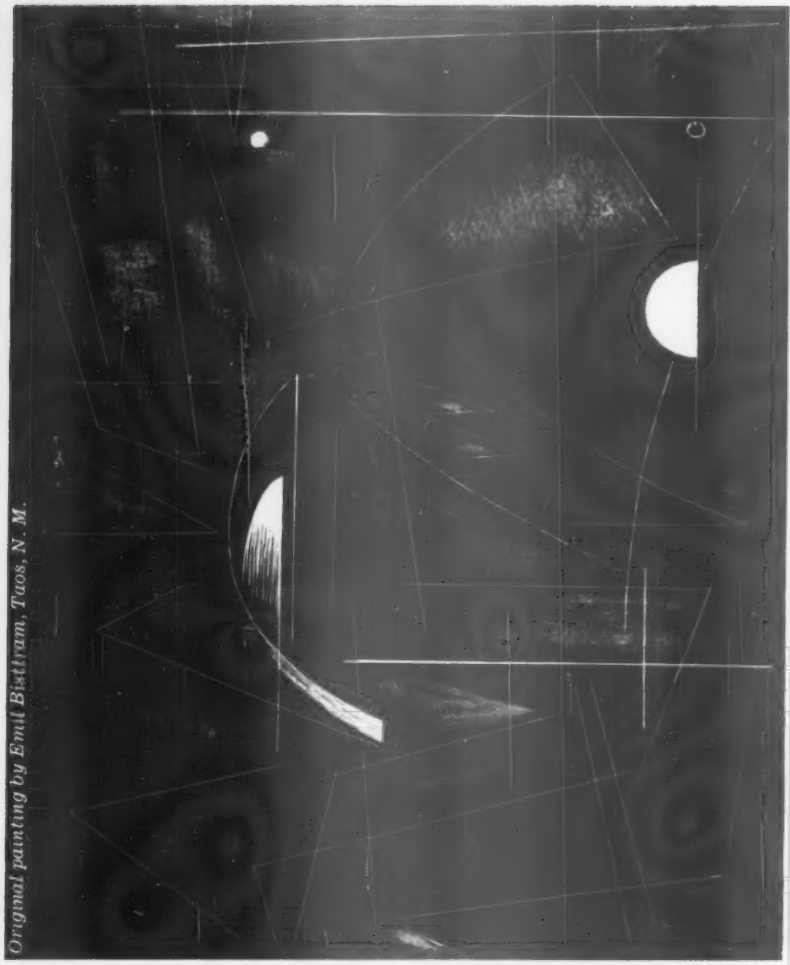

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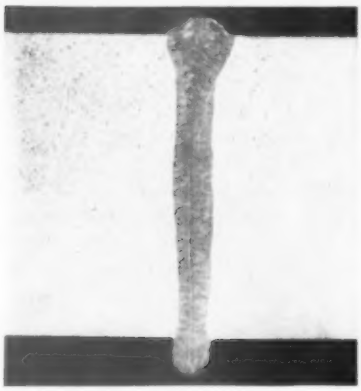

Figure 1

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Figure 2

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Figure 3

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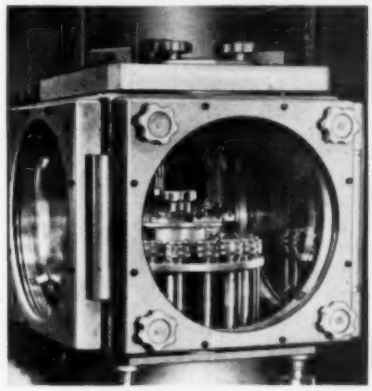

Figure 4

As shown in Figures 3 and 4, complete accessibility and visibility are provided by this latest Sciaky design. All sequence controls of the dial feed unit (Figure 4) are fully automatic. This production unit is being used to weld end-caps to tubes.

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Ozone Analyzer Uses Radioactive Clathrate

By CARLTON O. HOMMEL, DAVID CHLECK* and FREDERICK J. BROUSAIDES
Tracerlab, Waltham, Massachusetts

Ozone concentration can be measured by running a gas stream over a Kr^{85}-containing quinol clathrate (*1*) and observing the amount of radioactivity released. We have developed a detector based on this principle and find that it has many advantages over conventional ozone analyzers. It is rugged, portable and inexpensive. It contains no solutions. With a specific activity of 1 curie/gm the instrument will detect ozone concentrations in the parts per ten billion range or smaller. It is appropriate for either batch or continuous analysis.

Ozone Analysis

In the past there have been three principal methods for measuring ozone concentration. In one method the gas stream is bubbled through a solution of potassium iodide, which is oxidized to release free iodine (*2*). The iodine is measured by thiosulfate titration or colorimetery.

A fluorescent method uses either the oxidation of a fluorescent substance (like fluorescene) to a nonfluorescent one or the oxidation of a nonfluorescent substance (for example, dihydroacredine) to a fluorescent one (*3*).

A third method uses the absorption of visible or ultraviolet light by ozone (*4*). An important disadvantage is that the system responds to colored contaminants and dust.

A method newer than the better known three is that of the Goodrich Ozonometer (*5*), which has great sensitivity (parts per billion). It depends on the cracking of stretched rubber by the action of ozone.

None of these methods is suitable for field use, since they depend on liquid absorbants, constant-potential supplies and bulky batteries. There has long been a need for a portable, light, rugged and specific ozone analyzer.

Our Apparatus

Into our ozone detector air, laden with ozone and water vapor, is pulled by a pump through a drier that contains Linde Molecular Sieve No. 4A ($\frac{1}{16}$-in. pellets) (Fig. 1). After water vapor is removed, the ozone-containing air stream enters a radioactive reaction bed where the ozone reacts and releases Kr^{85}. The krypton is swept from the bed into the air stream and enters a detector that contains a G-M tube. Decaying krypton atoms are counted with scaler or ratemeter. Velocity of the air stream is controlled by a flow valve.

The detector, a Tracerlab TGC-6 G-M tube, is thin walled (30 mg/cm²) and filled with argon and an organic quenching gas. The tube is enclosed

* PRESENT ADDRESS: Parametrics, Inc., Waltham, Mass.

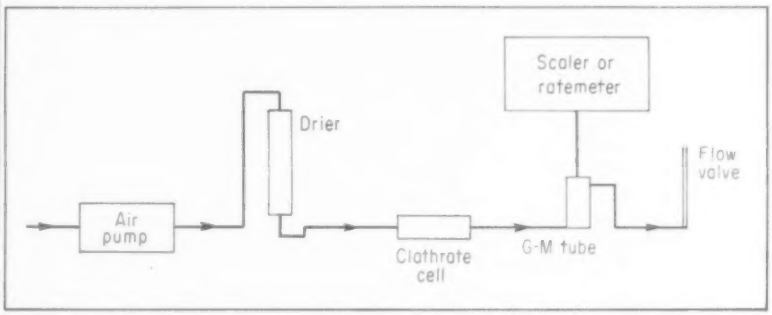

FIG. 1. OZONE ANALYZER dries air and passes it over Kr^{85}-containing clathrate. Ozone attacks clathrate, releasing Kr^{85} to produce signal in G-M tube

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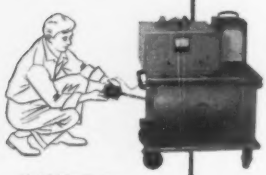

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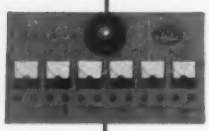

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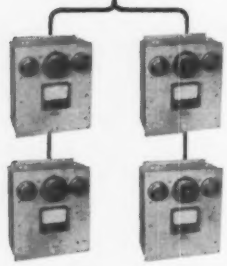

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NMC INDIANAPOLIS

Ozone Analyzer

This article starts on page 94

in a stainless-steel chamber of such a size that the volume between tube and chamber is 50 cm³.

Reaction Bed

The Kr^{85} atoms are completely contained in the clathrate of the reaction bed unless the forces that bind the quinol crystal together are overcome (*6*). Ozone oxidizes quinol to quinone to liberate the krypton:

$$(C_6H_4(OH)_2)_3 \cdot Kr^{85} + O_3 \rightarrow 3C_6H_4O_2 + 3H_2O + Kr^{85}$$

We have used clathrates of two specific activities, 0.1 c/gm and 1.0 c/gm. The finished clathrate is ground to a powder, sealed in a small glass tube, and coupled to the rest of the flow system with flexible Tygon tubing. Replacing the clathrate consists in merely removing this piece of glass tubing and substituting a fresh one.

We have never exhausted a clathrate of its Kr^{85}, although some have been used constantly for several months. After long exposure to humid air, however, sensitivity is somewhat decreased. This is accompanied by obvious changes in the appearance of the clathrate; it turns from brown to black and is visibly wet.

Testing Procedure

We have tested our instrument by making ozone in a generator that operates with a silent electrical discharge in dry air (*7*). To calibrate the generator we passed its output into a potassium-iodide solution and titrated for liberated iodine. Thus the amount of ozone in the air leaving the generator was known as a function of applied transformer potential.

Since the performance of the generator could not be measured chemically in a reasonable length of time for transformer settings less than 100 volts because of the small rate at which ozone is evolved, we have made our calibrations in terms of transformer settings. The curves that relate transformer settings to ozone concentration are shown in Fig. 2.

To make a test we adjusted the generator to give a constant supply of air of known ozone concentration and passed the stream over the clathrate at 50 cm³/min. Counting rate was determined at 1-min intervals until it became constant. The test was repeated over a range of generator

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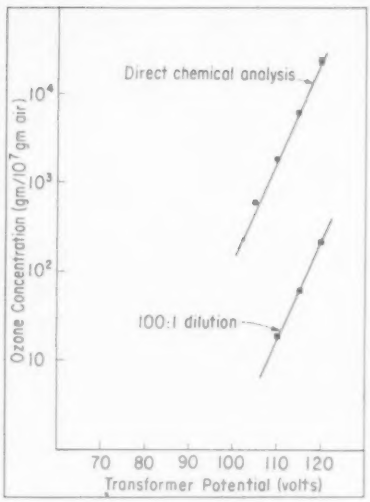

FIG. 2. GENERATOR CALIBRATION shows ozone concentration vs. potential

settings from 80 to 120 volts and then repeated with the output of the generator diluted in a hundred-to-one ratio with pure air.

To observe stability we ran a constant concentration of ozone over the clathrate for 2 hr. To watch recovery we turned off the generator and followed the counting rate for another 15 min as it declined.

Response

Our tests show that the instrument is fast, sensitive and specific. When ozone strikes the reaction bed, krypton is released immediately and the counting rate rises sharply from background and then levels off at a constant value (Fig. 3). The buildup time may be in part due to ozone buildup in the generator; no attempt has been made to form an ozone concentration before applying it to the clathrate. Recent development has decreased the lag so that the instrument will follow variations in ozone concentration within 2–3 min.

Sensitivity. The system has better sensitivity than other ozone-analysis instruments because it depends on the counting of radioactivity. For example the limit with potassium iodide appears to be 0.1 ppm. We feel that our eventual limit is a few parts in ten billion.

Figure 4 shows calibration curves for the detector operating with both 0.1 c/gm and 1.0 c/gm clathrates.

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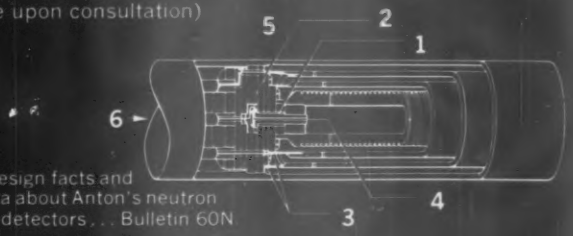

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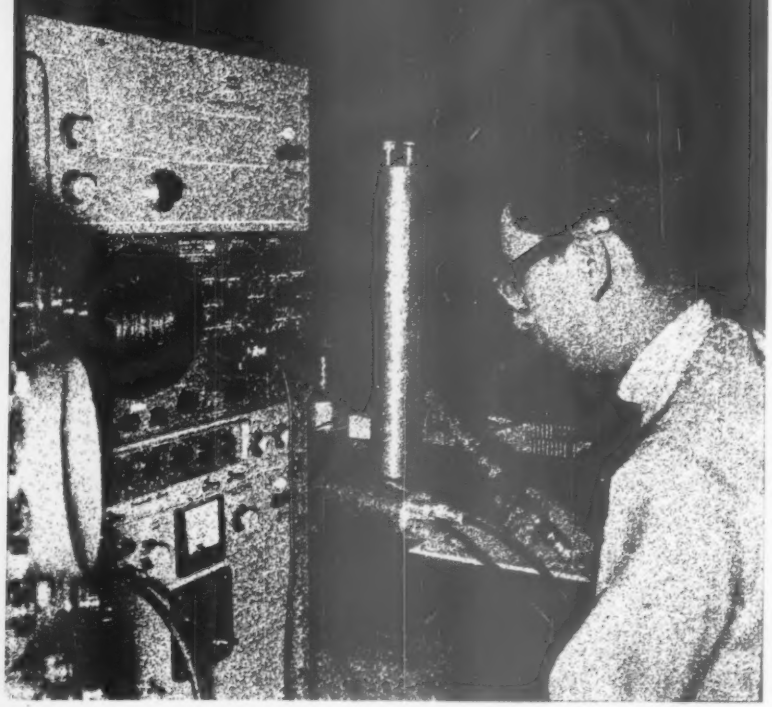

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Ozone Analyzer

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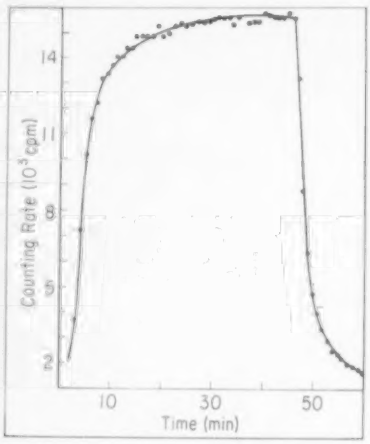

FIG. 3. RESPONSE rises rapidly as device is exposed to ozone, falls rapidly as ozone generator is turned off

The dotted portion of the 0.1 c/gm curve is extrapolated, but recent experiments reaching an ozone concentration of 5×10^{-11} by weight verify the extrapolation. Thus a counting rate of 100 cpm corresponds to an ozone concentration of 5×10^{-11} by weight.

The few experimental points with the stronger clathrate show counting rates for a given ozone concentration about twice as great as those with the weaker one. In view of the slopes of the curves, this suggests a sensitivity to ozone about ten times as great for one as for the other. Comparison of the results with the two clathrate strengths suggests a $\frac{1}{3}$-power response to both ozone concentration and clathrating efficiency. Clathrating efficiency determines the concentration of Kr^{85} in the cages on the surface.

Specificity. The relatively large negative value of the oxidation potential of the quinol-quinone couple means that only strong oxidizing agents such as ozone, nitrogen dioxide and chlorine dioxide will release krypton. Thus the device can be made more specific than presently used techniques for ozone analysis. It is impossible for many airborne contaminants (SO_2, NO, etc.) to react with the clathrate. Those that do can be readily removed from the air stream by other means. For example the clathrate responds to water vapor in the air because water dissolves the cage walls. But Molecular Sieves block the water and quantitatively pass the ozone.

(Continued)

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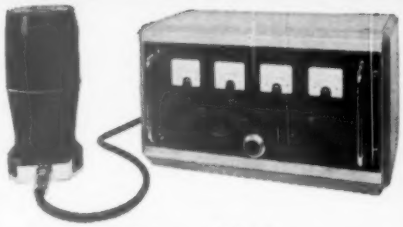
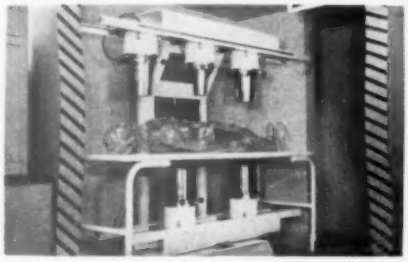


Environmental Monitor



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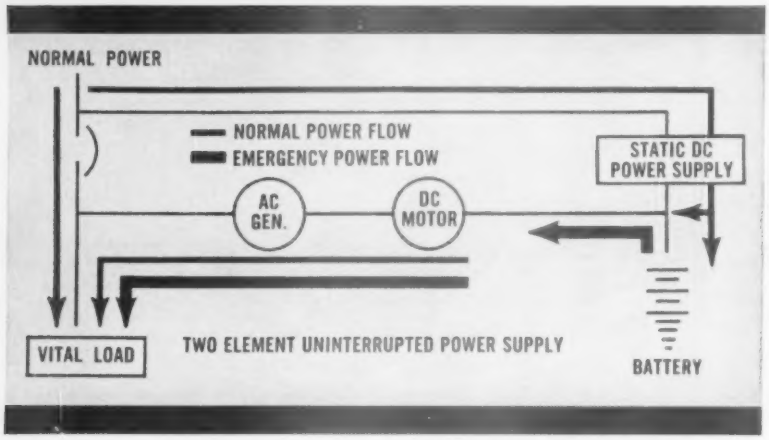

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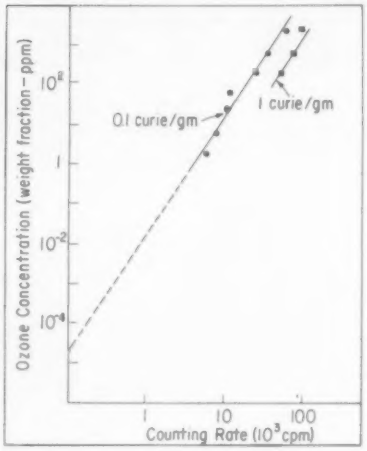

FIG. 4. INSTRUMENT CALIBRATION indicates linear response and potential sensitivity of 1 part in 10 billion by weight

Even though the present device is specific for the strongest oxidizing agents, modifications will make it suitable for detection of other gases. To obtain a response with reducing agents, for example, one first causes them to react with sodium chlorite ($NaClO_2$), which quantitatively releases chlorine dioxide; this then releases krypton as does ozone.

Other gases we have detected in our laboratory by these means include sulfur dioxide, hydrogen sulfide, nitric oxide, nitrogen dioxide, chlorine, chlorine dioxide and hydrazene. Thus further application of the principle will probably provide a useful tool in air pollution, process control, meteorology and many other fields.

* * *

This work was conducted under a contract from the Office of Isotopes Development, AEC. The authors wish to express their thanks for the assistance and advice rendered by the members of this office during the course of the work.

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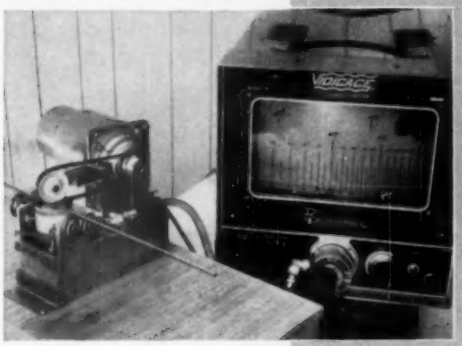

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Authors, Readers and Publishers

ALVIN M. WEINBERG, *Oak Ridge National Laboratory, Oak Ridge, Tennessee*

I have been asked by the editors of NUCLEONICS to urge nuclear energy people to spend more time reading the nuclear-energy literature. As one who has often asked that we develop a scholarly tradition in nuclear energy (*1*), it would be in poor taste for me not to persuade everyone in the field to read more and more of the relevant literature. And indeed I think, on the whole, we do not read enough of the literature. Nuclear-energy people are too busy building reactors or selling reactors (literally and figuratively) to spend as much time as they should reading widely in their specialty. It is important that they do more reading, and I am all for it.

But there is another side to the picture. How much of the current, and ever-increasing, outpouring of nuclear-energy books, articles, theses, review journals, abstract journals, newsletters, newspapers, magazines—even tip sheets—is worth reading? The ratio of verbiage to solid accomplishment in nuclear energy has, in my opinion, exceeded what is reasonable. For example, I don't think that every publisher need have his own nuclear-energy series; or that we need in America three nuclear newsletters; or, for that matter, three highly-technical nuclear-energy journals in English. We are being snowed by a torrent of printed nuclear words.

The bad effects of this outpouring are many. First, I think that, on the whole, insufficient time and energy—not to say competence—goes into the supposedly serious nuclear-energy literature. There are more publishers who sniff money in the nuclear publishing business and who want nuclear-energy books than there are competent authors to fulfill the demand. Under the circumstances the time and care and patience required to produce first-rate scientific writing is too often absent. One publisher explained to me that every technical book today has a guaranteed sale to technical libraries (many of them supported by government money) of about 3,000 copies. Is there much incentive for excellence when the market will accept everything—good, bad, indifferent?

With so much of the literature written on such a vast scale, what is written doesn't really get read. The usual give-and-take of science in which each scientist who has something to say says it publicly with the expectation and right to be refuted if what he says is nonsense—this is giving way to an inevitable kind of neutral I-don't-care-

ism. I-don't-care science is the sure progenitor of poor science. If what is written is not read—either because too much is written, or because what is written is not done well, or because people are out of the habit of reading—then surely science will deteriorate.

A recent personal experience with the book that Professor Wigner and I wrote on chain reactors bears out my belief that what is written doesn't get read, and that therefore either too much is written or too little is read. Our book was first published in September, 1958. Unfortunately, there were all too many misprints and minor errors in it. Since the book was printed, we have received lists of misprints sent in by attentive readers and critics. We had thought that all of the important slips had been noted. Imagine our surprise a few months ago, some two and a half years and many thousands of copies after "The Physical Theory of Neutron Chain Reactors" had been published, when we were presented with a brand new list of misprints and errors about as long as the entire previous list, carefully noted by a group of Argonne reactor students. I do not say that every purchaser of "The Physical Theory of Neutron Chain Reactors" has an obligation either to read the book carefully or to cull it for errors. I do say that in this case, out of many thousands of readers, there were only a few who had read the book fully critically, or who cared enough to complain to the authors about shoddiness in their product.

The twofold complaint that I make about the nuclear-energy literature—that there is too much of it, and that it doesn't get read—is a trouble not unique to nuclear energy. It is a trouble which affects all branches of science, and is at least in part caused by the enormous expansion of science. However, I think the trouble is compounded by over-aggressive publishers who try to milk science of as much written material as possible. Whatever the cause, if what is written in science is not read, if the product of scientific activity is not subjected to the critical scrutiny of those competent to criticize, something deeply essential will have been lost from science.

In nuclear energy there is a factor that makes the situation worse. Nuclear energy is largely publicly supported, and it is surrounded by an aura of glamor. As a result, writings about nuclear energy often have a journalistic quality that I believe intrudes on the serious literature. The line between science and journalism must be drawn sharply and hard—otherwise journalism will tend more and more to take over science. Serious workers in nuclear energy certainly can use popularized accounts of what is happening in their field; I myself enjoy reading NUCLEONICS WEEK. But they need even more to study the serious—and maybe a little difficult—literature of nuclear energy.

There is an unwritten compact between a scientific author and his reader—namely, that the author has a responsibility to expound the truth to the ultimate limit of his capacity, even if this requires harder work than he was originally prepared to put into his writing. If nuclear-energy authors remain scrupulously true to this compact, I think nuclear-energy people would be more inclined to read what they must—the serious literature of nuclear energy.

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What's on the Scientists' Bookshelves?

With a thought to finding out what specialists in the nuclear field are reading, we asked those listed below to tell us which nuclear books they reach for most frequently in their libraries and why. The answers are interesting and give an insight into some of the most important books published in these particular nuclear fields.

Reactor Theory—Bernard I. Spinrad

(He's Director, Reactor Engineering Division, Argonne National Laboratory, Argonne, Ill.)

"Elements of Nuclear Reactor Theory" by S. Glasstone and M. C. Edlund (D. Van Nostrand Co., Inc., Princeton, N. J., 1951)

Although this is the oldest of the major texts in this field, I still consider it the best. It is somewhat clearer and more compact than later competitive texts and contains essentially the same material at an equivalent level.

"Methods of Theoretical Physics" vols. 1 and 2 by P. M. Morse and H. Feshbach (McGraw-Hill Book Co., New York, 1953)

These two volumes are my basic reference and browsing set when a physical problem requires me to seek additional mathematical background.

"Reactor Physics Constants" (ANL-5800)

It would be surprising if I did not list this work, which, along with certain textbooks, makes most older handbooks obsolete. I also find that ANL-5800 has a salutary effect on the report and reprint requirements of my office since it reduces the number of these volumes that I need.

"Neutron Cross Sections" (BNL-325)

This book, which is the primary data book on the subject, is useful for qualitative cross-section curves, resonance-parameter listings and as a bibliography source.

Geneva Conference Volumes: "Physics of Reactor Design," 1955, vol. 5; "Reactor Safety and Control," 1958, vol. 11; "Reactor Physics," 1958, vol. 12; "Reactor Physics and Economics," 1958, vol. 13; "Nuclear Data and Reactor Theory," 1958, vol. 16.

Taken together, these volumes form a very comprehensive series of review articles. Their publication is a major blessing to the nuclear field and justifies holding the conference.

Nuclear Propulsion—Jerry Grey

(Dr. Grey is at Princeton University, Princeton, N. J.)

Because of the relatively new field of applying nuclear energy to propulsion systems, "hard-cover" literature has not yet had time to develop. Much of the field is classified and most of the unclassified materials still appear in the form of papers, journal articles, etc. Hence, the list of "essential" books that follows is short.

"Principles of Nuclear Reactor Engineering" by S. Glasstone (D. Van Nostrand Co., Inc., Princeton, N. J., 1955)

This volume is quite useful as an introduction to the over-all reactor program, particularly for engineers with little or no physics background.

"Reactor Analysis" by R. V. Meghreblian and D. Holmes (McGraw-Hill Book Co., New York, 1960)

Perhaps the most complete reactor-analysis textbook available, this book more than adequately fills the need for detailed nuclear-design requirements.

"The Dynamics and Thermodynamics of Compressible Fluid Flow" vols. 1 and 2, by A. H. Shapiro (Ronald Press, New York, 1953)

This book covers all the areas necessary for gas-cooled reactor-flow analysis.

"Nuclear Rocket Propulsion" by R. W. Bassard and R. D. DeLauer (McGraw-Hill Book Co., New York, 1958)

This edition provides a good introduction to the specialized problems involved in the application of nuclear energy to rocket power plants.

"Physics of Fully Ionized Gases" by L. Spitzer (Interscience Publishers, New York, 1956)

This is a good reference book in the area of extreme-temperature gases for advanced fission and possible fusion power plants in the future.

Nuclear Engineering—Charles F. Bonilla

(Bonilla, himself an author, teaches nuclear engineering in the Department of Chemical Engineering, Columbia University, New York, N. Y.)

The books that a nuclear engineer uses and even the ones he may find "indispensable" depend on the field in which he is working and to a considerable extent on the level of his work. Since in my own case I teach courses in Nuclear Engineering Laboratory, Nuclear Chemical Engi-

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N. G. SJOSTRAND, *A. B. Atomenergi, Stockholm, and* J. S. STORY, *A.E.R.E., Harwell*

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Vol. III Fission Parameters and Fast Neutron Cross Sections

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In preparation

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neering and Nuclear Reactor Thermal Design, I have chosen books from these three fields for my list of important nuclear-engineering books.

"Radioisotope Techniques" by R. T. Overman and H. M. Clark (McGraw-Hill Book Co., New York, 1960)

"Nuclear Reactor Experiments" by J. B. Hoag (D. Van Nostrand Co., Inc., Princeton, N. J.)

"Reactor Analysis" by R. V. Meghreblian and D. Holmes (McGraw-Hill Book Co., New York, 1960)

Although we do not specify a particular text in the Nuclear Engineering Laboratory, we make frequent reference to Overman and Clark's book for the radiochemical experiments because of its extensive background information and its experimental procedures. Hoag is used for experiments on subcriticals. Because of its completeness and readability, Meghreblian and Holmes' book gives excellent general-reactor coverage.

"Nuclear Chemical Engineering" by M. Benedict and T. Pigford (McGraw-Hill Book Co., New York, 1957)

"Symposium on the Reprocessing of Irradiated Fuels," vols. 1, 2 and 3 (AEC publication, Brussels, 1957)

In Nuclear Chemical Engineering the Benedict and Pigford text is the only volume we know with broad enough coverage of this field for a first-year graduate course. For more information on the specific topic of fuel reprocessing, the AEC Symposium volumes (TID 7534) are useful.

"Nuclear Engineering" by Charles F. Bonilla (McGraw-Hill Book Co., New York, 1957)

"Control of Nuclear Reactors and Power Plants" by M. Schultz (McGraw-Hill Book Co., New York, 1955) (New edition, March, 1961)

In the Thermal Design course I must admit that I use my own book, principally because I know what is in it and where. Although originally conceived for a graduate-level survey course in nuclear engineering, the fluid-flow, heat-transfer and thermal-stress chapters are quite extensive as well as entirely related to nuclear design. Monty Schultz's book is valuable for predicting transient response.

"Nuclear Engineering Handbook" by H. Etherington (McGraw-Hill Book Co., New York, 1958)

"Reactor Handbook," Engineering and Materials Volumes (Interscience Publishing Co., New York)

These two books provide general references where data, correlations or methods can be sought.

Because of the rapid development in the nuclear field, however, all of these books should be supplemented with files of reports, reprints, AEC press releases, *Nuclear Science Abstracts*, etc. kept as up-to-date as time and space allow. Particularly useful from my point of view are the recently published survey volumes of the AEC's Civilian Power Reactor Program. (NU, Apr. '60, p. 71)

Applied Radiation—Vincent P. Guinn

(Dr. Guinn is Supervisor, Radiochemistry Group, Shell Development Co., Emeryville, Calif.)

"Beta- and Gamma-Ray Spectroscopy" by K. Siegbahn (Interscience Publishing Co., New York, 1955)

"The Atomic Nucleus" by R. D. Evans (McGraw-Hill Book Co., New York, 1955)

"Fast Neutron Physics," Part I of Techniques (Interscience Publishing Co., New York, 1960)

"Luminescence and Scintillation Counters" by S. C. Curran (Academic Press, New York, 1953)

"Scintillation Counters" by J. B. Birks (McGraw-Hill Book Co., New York, 1953)

These books are of prime interest to me because of their thorough treatment of such topics as nuclear structure, nuclear interactions, radioactive decay, interaction of radiation with matter, scintillation processes and gamma-ray spectrometry.

"Liquid Scintillation Counting" edited by C. G. Bell and F. N. Hayes (Pergamon Press, New York, 1958)

This book gives the only thorough treatment of the subject of liquid-scintillation counting.

"Nuclear and Radiochemistry" by G. Friedlander and J. Kennedy (John Wiley, New York, 1955)

"Modern Radiochemical Practice" by G. B. Cook and J. F. Duncan (Oxford University Press, 1952)

These books are, in my opinion, two of the best in the treatment of the whole field of radiochemistry.

"Radioisotope Techniques" by R. T. Overman and H. M. Clark (McGraw-Hill Book Co., New York, 1960)

This is the only up-to-date book with detailed treatment of almost all radiochemical laboratory techniques.

"Principles of Nuclear Engineering" by S. Glasstone (D. Van Nostrand, New York, 1955)

This book gives a very thorough presentation of the subject of nuclear reactors. To this list might well be added several smaller booklets that are of considerable practical use—the Oak Ridge National Laboratory Catalog, the Isotope Index (Scientific Equipment Co., Indianapolis, Indiana) and the National Bureau of Standards Handbooks 42, 51, 59, 63 and 69.

Nuclear Instrumentation—Robert L. Chase

(Bob Chase, author of a forthcoming McGraw-Hill book on scintillation spectrometry, is at Brookhaven National Laboratory, Upton, New York)

The following books are the most useful in the nuclear-instrumentation field.

"Electronics," by W. C. Elmore and M. Sands, vol. 1 in National Nuclear Energy Series (McGraw-Hill Book Co., New York, 1949)

"Signal Noise and Resolution in Nuclear Particle Counters" by A. Blackley and A. B. Gillespie (Pergamon Press, New York, 1953)

"Ionization Chambers and Counters" by B. Rossi and H. A. Staub, vol. 2 in National Nuclear Energy Series (McGraw-Hill Book Co., New York, 1949)

"Ionization and Counters" by D. Wilkinson (Cambridge University Press, 1950)

"Scintillation Counters" by J. B. Birks (McGraw-Hill Book Co., New York, 1953)

AEC Technical Information Services

By EDWARD J. BRUNENKANT and RICHARD M. BERG
Office of Technical Information, Atomic Energy Commission, Washington, D. C.

> *"The dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free interchange of ideas and criticism which is essential to scientific and industrial progress and public understanding and to enlarge the fund of technical information."* (Chapter 12, Sec. 141 b.—Atomic Energy Act of 1954)

The AEC is the fourth largest Federal sponsor of research and development, exceeded only by the Army, Navy and Air Force. It is, of course, the preeminent sponsor in the nuclear field. In the current fiscal year AEC will spend more than $800 million for acquiring new knowledge of the atom and for developing nuclear applications, in the broad sense—technical information. It is obvious, therefore, that technical information is one of the AEC's most important products.

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Responsibility for the AEC technical information program is centered in the AEC Office of Technical Information. OTI consists of two branches: a Washington staff and the Office of Technical Information Extension at Oak Ridge, Tennessee. In the broad division of labor between the two groups, OTI Washington is responsible for over-all policy and program direction as well as planning and administrating specialized programs. The Extension, on the other hand, manages the technical-report distribution system, develops and publishes bibliographic and reference tools, provides reference services, conducts an aggressive information-acquisition program, provides translation services through contractual arrangements (see p. 111) and offers publishing services in support of other OTI programs.

Technical Reports

The nearly 40,000 technical reports prepared by AEC contractors constitute the hard core—the "bread and butter"—of the AEC technical-information dissemination program. The AEC estimates that more than 6,000 unclassified reports will be issued during this fiscal year alone.

These AEC technical reports are sold by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. and, are also available in microcopy from the Microcard Corporation, Madison, Wisconsin.

Not all work, however, is reported in document format. For instance, AEC contractor scientists publish several thousand articles a year in scientific and technical journals. In addition, they report extensively at professional meetings and conferences. The proceedings are published by the AEC and sold by the Office of Technical Services.

Nuclear Science Abstracts

The best way for scientists and engineers to keep up with the burgeoning nuclear literature is to read *Nuclear Science Abstracts*. Published by the AEC since 1947, this semimonthly abstract journal is the key not only to AEC report literature but also to report, journal, book and patent literature the world over. It is the fifth largest abstract journal published in the United States and the only one with complete indexes in each issue. The indexes, containing personal author, corporate author, report number and subject are cumulated quarterly, semiannually and annually. Three multivolume indexes have already been published; others will be published at five-year intervals.

NSA is available on subscription from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. at a one-year domestic subscription (including all indexes) of $33.00.

Besides NSA the AEC publishes a number of other bibliographic and reference aids. These include bibliographies, literature searches and report lists—all are sold by the Office of Technical Services.

Technical Books

From its inception the AEC has sponsored the writing and publication of scientific-engineering books and monographs to foster progress in nuclear science and technology. Nearly 100 AEC-sponsored books have been published including the 30-volume National Nuclear Energy Series "Presentation Sets" for the two Geneva Conferences (11 volumes in 1958 and 9 volumes in 1955) and the highly successful nuclear works of Samuel Glasstone. "Materials," the first volume of the second edition of the "Reactor Handbook," has already been published commercially. In addition, the AEC has recently joined with several professional societies to produce short (200 pages or less) paperback monographs on nuclear-energy subjects.

Progress Reviews

To meet the needs of science and industry for concise periodic summaries of significant developments in key areas of nuclear science and technology, the AEC in 1957 initiated the publication of quarterly "Technical Progress Reviews." Four Reviews have been published so far: "Power Reactor Technology," by Walter H. Zinn and his associates of the General Nuclear Engineering Corporation; "Reactor Fuel Processing," by Stephen Lawroski and his associates of the Argonne National Laboratory; "Reactor Core Materials," by R. W. Dayton, E. M. Simons, and their associates of the Battelle Memorial

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Institute; and "Nuclear Safety," edited by W. B. Cottrell and R. A. Charpie and their associates at the Oak Ridge National Laboratory. The Reviews are sold on subscription by the Superintendent of Documents for $2.00 a year each.

Depository Libraries

To provide ready and convenient access to its unclassified materials, the AEC has established a far-flung system of 85-domestic and 84-foreign depository libraries. Each contains a complete collection of AEC reports and bibliographic tools, including NSA and other AEC technical literature. Depository libraries in the United States also contain copies of reports from foreign countries that have bilateral agreements with the United States. Each institution serving as an AEC depository agrees to service the collection and to provide reference, loan and document reproduction services.

Educational Services

To foster public understanding of nuclear enterprise and to stir the imagination of our future scientists, the AEC sponsors a program of traveling exhibits and demonstrations, carried out through the Oak Ridge Institute of Nuclear Studies. In the high-school demonstration program a trained demonstrator, equipped with suitable "props," goes into the science classes and puts on lively exhibitions of the scientific principles and applications of atomic energy.

Requests for exhibits and demonstrations should be directed to the Oak Ridge Institute of Nuclear Studies, Post Office Box 117, Oak Ridge, Tennessee.

Motion Picture Films

The AEC and its contractors have recorded valuable information on motion picture films. More than 80 professional titles and 80 popular titles covering the gamut of nuclear-energy subjects are available for non-profit group showings. Professional societies, civic organizations and industrial organizations are invited to borrow films from the AEC's 10 motion-picture film libraries at AEC Headquarters and field offices. AEC film libraries service only the United States and Canada; prospective borrowers from other countries should contact the United States Information Agency office serving their country. The AEC's film program is administered by the Office of Public Information.

Keeping Up With Foreign Nuclear Literature

No less important than the flood of English-language nuclear literature are the periodicals and books that describe the work of nuclear scientists and technicians abroad. To help people who can read only English keep abreast of world literature, government and private organizations are busy abstracting, translating and publishing books, articles and cover-to-cover journals from foreign countries—especially behind the Iron Curtain.

Just who is making nuclear translations and how can you get hold of them? Government organizations provide the most extensive translating and abstracting programs: The Office of Technical Services acts as a clearing house and selling office, the AEC makes nuclear translations and abstracts and the National Science Foundation acts as a financing organization. In addition, private publishers also translate and abstract a large number of articles and books each year. The box below shows where you can find out about these different publications.

Translation Depositories

The two major translation depositories in the United States are the Office of Technical Services (OTS) of the U. S. Department of Commerce and the Special Libraries Association Translation Center (SLA) at the John Crerar Library in Chicago. The OTS acts as a national translation "clearing house" to collect, catalog, reproduce and distribute translations made by agencies of the Federal Government and government agencies abroad; it also provides information on translations available from any other source, public or private. The OTS works in close cooperation with the SLA, an organization that collects translations and abstracts from private organizations. All translations are listed with abstracts of the articles in *Technical Translations* published bimonthly by the OTS. This publication contains about 1,200 new items each month (see box).

Because of a lack of public demand for cover-to-cover abstracting of about 140 Russian technical journals, the OTS has recently abandoned this part of its abstracting program. In its place OTS has instituted a selective abstracting service of about 200 Russian, Communist Chinese and other difficult-to-read technical journals.

AEC Translations

As might be expected, the government agency carrying out the most extensive nuclear-literature translation program is the Atomic Energy Commission (see p. 109). Their program is administered by the Office of Technical Information Extension in Oak Ridge, Tennessee. The major objectives of the AEC are to collect and disseminate translations sponsored by AEC contractors and other agencies here and abroad, to coordinate the translation activities of AEC contractors (and thus avoid duplication) and to provide translations of monographs and books—particularly from Russian. Translations sponsored by AEC contractors are available in OTS and SLA depository libraries as well as the AEC's own libraries. These translations with abstracts are announced in *Nuclear Science Abstracts*. In addition, the Office of Technical Information (OTI) intends to publish shortly a listing of about 7,000 translations in *Translation Title List and Cross Reference Guide*.

The OTI directly contracts for the translation of foreign-language materials with the emphasis on nuclear books and monographs. Most of these works are printed by OTI, distributed to AEC contractors, official agencies and AEC depository libraries and sold to the public through the Office of Technical Services.

Through the OTI, the AEC also contributes information about nuclear translations and abstracts to the *Transatom Bulletin*, the EURATOM monthly publication that announces translations prepared by EURATOM member organizations along with these prepared in the United States and the United Kingdom.

National Science Foundation

The National Science Foundation, the supporting organization for many

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Office of Technical Services

"Technical Translations" Contains lists of all foreign translation along with abstracts. One quarter of the translations are available from OTS. Microfilm copies also available. Bimonthly, $16 a year. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

"Current Review of the Soviet Technical Press." Reviews books and articles on all sciences within a month of publication in Russia. Weekly, $7 a year. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.*

"Translators and Translations: Services and Sources." Directory of translators and translation pools throughout the world and a bibliography of translation indexes. *Special Libraries Association Center, John Crerar Library, Chicago, Ill.*

Atomic Energy Commission

"Nuclear Science Abstracts." Announces translations and includes abstracts of nuclear literature. Semimonthly, $33 (domestic including indexes). *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

"Translation Title List and Cross Reference Guide" (TID-4025) (1st Rev). Contains about 7,000 nuclear translations held by OTI. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

EURATOM

"Transatom Bulletin." Compilation announcing translations prepared by EURATOM member organizations. Monthly, $8 a year (surface), $16 a year (air mail). *EURATOM, Transatom Service, 51 Rue Belliard, Brussels.*

National Science Foundation

"Providing U. S. Scientist with Soviet Scientific Information." Rev. ed. Information about translations of books and periodicals available in U. S. *Office of Scientific Information Service, National Science Foundation, Washington 25, D. C.*

"List of Russian Scientific Journals Available in English" (NSF 60-46), *Office of Scientific Information Service, National Science Foundation, Washington 25, D. C.*

Library of Congress

"Monthly Index of Russian Accessions." Bibliographies issued in Soviet Union, available in U. S. $12 a year. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

"East European Accession Index." Record of monographic publications in Iron Curtain countries and Yugoslavia. Monthly, $10 a year. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

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May 1961, about 500 pp., illus.

Nuclear Spectroscopy
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Part A, *1960, 621 pp., illus., $16.00*
Part B, *1960, 524 pp., illus., $16.00*

Nuclear Physics
Edited by LUKE C. L. YUAN *and* CHIEN-SHIUNG WU
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Part B, *1961, in preparation*

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By MARTIN D. KAMEN
1957 (2nd printing, 1959), 478 pp., illus., $10.50

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By R. C. KOCH
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nuclear translations, finances programs for translating foreign-language scientific and technical material. Included are cover-to-cover translations of journals by scientific societies as well as a number of books and monographs for commercial publishers. The NSF helps support cover-to-cover translations of 45 Soviet technical journals.

In addition, they organize the government program of buying translations from abroad, using money received from countries that get food surplus from the United States. For example, Israel is now translating about 50,000 pages of Russian material, Poland will soon translate 19,000 pages of Polish scientific and technical literature and Yugoslavia will translate 20,000 pages of Serbo-Croatian and other East-European literature.

Private Publishers

In addition to these government translation organizations, several private publishers put out foreign books and journals. Two of the most extensive programs are conducted by Consultants Bureau Enterprises and the Pergamon Press. To avoid duplication by other organizations planning Russian translations, Consultants Bureau distributes quarterly a list of the books they plan to translate.

Success of Programs

How well do these organizations work and cover the ever-increasing mass of foreign literature pouring into the United States? Pretty well, according to a recent NUCLEONICS survey. The time-lag between the date literature appears in a foreign country and the time an abstract or translation is published in this country is not great enough to lessen its usefulness. For the most part, the 3-month-or-greater time lag is being reduced. In addition, there seems to be very little overlapping of effort or material translated, since the OTS *Technical Translations* keeps all organizations up to date on publications being translated or abstracted. The translators also appear to do their job well. Since many of them are trained scientists, or at least have some scientific background as well as a fluent knowledge of both English and the language of the article, the translators introduce few errors into the translating and abstracting process. Thus, although improvements can always be made, the system as it now stands appears to keep nuclear scientists adequately aware of the developments in their field abroad.

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Although based on a report prepared by Dr. Goldstein for the AEC (entitled **Attenuation of Gamma Rays and Neutrons in Reactor Shields**), this volume has been revised, corrected, and updated in many respects. For example:

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- Chapter 3 contains completely new photoneutron cross sections, as well as a complete revision of information on sources of radiation (e.g., new information on fission gamma rays and fission product gamma rays)
- Chapter 5 offers new appendixes which include: complete summary of moments method; gamma ray penetration calculations; summary of neutron penetration kernels; listing of capture gamma ray spectra
- One-third more literature references are included

Other reviewers have commented that this book "stands alone as the authoritative treatise" (**Nucleonics**), that it is the "best that has been published" (**Nuclear Physics**).

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A Nuclear Book Review

Arms Control, Disarmament and National Security

Edited by DONALD G. BRENNAN (George Braziller, Inc., New York, June, 1961, 512 pages, $6)

Reviewed by WILLIAM A. HIGINBOTHAM, Head, Instrumentation Division, Brookhaven National Laboratories, Upton, N. Y.

This book was originally published in the fall of 1960 with nearly the same content in the special arms control issue of Daedalus, *the Journal of the American Academy of Arts and Sciences.*

A couple of years ago it became possible to send a rocket to the moon. An off-the-cuff suggestion to explode a nuclear device on the moon brought a storm of protest from scientists who explained that we must not contaminate the moon if we want to study any natural radioactivity and plant life it may have. International conventions were called and within a matter of weeks there was international agreement to keep the moon scrupulously clean. But in fifteen years of almost constant international negotiation we have not been able to agree on how to keep from seriously contaminating the earth with radioactivity. And throughout these fifteen years the power to destroy has grown to the point where it is almost beyond comprehension.

Although it has been pretty obvious since Hiroshima that the arms race must be controlled, this vital subject has received little serious attention in or outside government circles until quite recently; this lack of attention is reflected in the paucity of relevant books or articles. "Arms Control, Disarmament and National Security" is a major contribution to this literature.

And this is a very complicated subject, which accounts to some extent for the lack of progress toward international agreements and for the lack of public understanding. Our national goal is not only peace, but peace with freedom and justice, and situations arise when all of our aims cannot simultaneously be achieved. Any unilateral actions on our part will affect Soviet policies; these in turn will affect our future choices, etc. An agreed reduction of armaments in one area requires a modification of the defense structure in other areas. Unilateral, bilateral and multilateral steps can affect the international atmosphere and the stability of the balance of fear. President Kennedy's recent defense-budget message considers these relationships as they affect our military program. Economic, social and emotional factors also affect the arms-control picture and they must be considered.

Since Sputnik there have been several small but careful studies of disarmament—some official and some private. The American Academy of Sciences has supported some of them. For its arms-control issue of *Daedalus*, the Academy sought contributions from people who were known to be interested and well-informed in the field. The result, an up to date and challenging source, will be published in book form this June. No one will say this is the last word, nor is it complete. But it is an excellent start on the research and debate that should have gone on in the past and must be pressed in the future. Survival is important to all of us and responsible citizens should welcome this opportunity to find out what the nuclear experts are thinking about.

Some Americans may be surprised by the historical articles that criticize the United States as well as the USSR for the failure of the disarmament negotiations. Although I don't agree altogether with Saville Davis's chapter in the book, I do think that America has certainly missed a lot of opportunities. From a casual reading of the papers it appears that the Soviets are always to blame. But careful reading of the *New York Times* and official documents leads me to think that this country has done very poorly since the spring of 1955.

The aims of arms control and the complexity of the problem are presented in the first three chapters of the book. Next is a very stimulating chapter by Herman Kahn, strategic analyst for the Rand Corporation and author of "Thermonuclear War" (Princeton University Press, Princeton, N. J., 1960), on the kind of world we live in and our chances of being alive a few years from now.

A few years ago Henry Kissinger

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wrote "Nuclear Weapons and Foreign Policy," which forced a reappraisal of American military and international thinking. His book also advocated nuclear weapons for limited warfare, in part, I suspect, to challenge people to think. In any event, his chapter in "Arms Control, Disarmament and National Security" tells why he now believes that this country should not use nuclear weapons in limited conflicts.

Among other topics covered are the role of lesser powers in the arms race, the problem of Red China, economic repercussions of disarmament, inspection, international law, public opinion, etc. One cannot possibly comment adequately on so many subjects in a review of finite length. Perhaps the subjects that are of greatest interest are test bans and comprehensive disarmament.

The test-ban chapter was written by Edward Teller who is quite frankly opposed to the bans. In retrospect, a test ban may have been a poor choice for the first step in disarmament, but since we agreed to negotiate the point, the West probably cannot back out without spoiling the chance of agreeing on anything else. I hope the test-ban picture is not as dark as Teller has painted it.

Comprehensive disarmament is interesting because it is the current Soviet proposal and both East and West have endorsed it in principle. The chapter on this subject is by Jerome Wiesner who recently became scientific advisor to the President. In many respects agreement on comprehensive disarmament is just about as easy to carry out as is a very limited agreement like the test ban—and a major reduction of armament would certainly result. But would all the nations involved be better off? The world power situation would be drastically changed and a very unstable situation might arise. Still comprehensive disarmament deserves very careful study.

Recently I accompanied a number of Americans to an unofficial international conference on disarmament in Moscow. The 21 Soviet delegates were the top scientific and technical men of the USSR. I think that most of us returned convinced that they were sincere in their desire for "full and complete" disarmament. But we also found out that they had not thought through the problems such a course would create. Neither have we to any appreciable extent. It's time we got to work.

New Books for Your Bookshelf

This preview list of nuclear books to be published this spring and summer should give you the appetite to follow Weinberg's advice: read more of "the serious literature of nuclear energy." The date of publication, if known, is set in italics; if no date appears, the book was either published earlier this spring or will be published later in the year.

Academic Press, Inc.

D. R. Bates, ed., "Radiation and High-Energy Physics," part C of Quantum Theory

A. DeShalit, I. Talmi, "Nuclear Shell Theory," *summer, 1961*

J. F. Flagg, ed., "Chemical Processing of Reactor Fuels," 500 pp., *May, 1961*

H. Kouts, E. J. Henley, ed., "Advances in Nuclear Science and Engineering," vol. 1

L. C. L. Yuan, C. Wu, eds., "Nuclear Physics," vol. 5 of Methods of Experimental Physics

W. S. C. Williams, "An Introduction to Elementary Particles," approx. 500 pp, *summer, 1961*

"Fuel Element Fabrication," Proceedings of IAEA Symposium in Vienna, 1960, 2 vol.

"Nuclear Science and Engineering," vol. 9–11, $19.50 each

Addison-Wesley Publishing Co., Inc.

J. L. Powell, B. Crasemann, "Quantum Mechanics," 494 pp, $9.75

Akademie-Verlag, Berlin

Bach, "Arbeiten uber Strahlenchemie"

W. Kunz, J. Schintlmeister, "Tabellen der Atomkerne," Teil 2, Band 1

American Society for Testing Materials

"Materials in Nuclear Applications STB—276," 344 pp, $8.25

"Symposium on Radioisotopes in Metals Analysis and Testing—STP 261," 68 pp, $2.75

"Symposium on Applied Radiation and Radioisotope Test Methods—STP 268," 112 pp, $3.75

Atomic Energy Commission

J. Belle, ed., "Properties of Uranium Dioxide"

J. Carroll, R. Bolt, "Effects of Radiation on Organic Materials"

A. S. Coffinberry, W. N. Miner, eds., "The Metal Plutonium"

S. Glasstone, "The Effects of Nuclear Weapons"

A. W. Kramer, "Commercial Nuclear Ship Propulsion"

Radiochemistry of the Elements, Monograph series:

The Radiochemistry of Rare Earths: Scandium, Yttrium and Actinium (NAS-NS 3020)

The Radiochemistry of Technetium (NAS-NS-3021)

The Radiochemistry of Vanadium (NAS-NS-3022)

The Radiochemistry of Tin (NAS-NS-3023)

The Radiochemistry of Magnesium (NAS-NS-3024)

The Radiochemistry of the Rare Gases (NAS-NS-3025)

The Radiochemistry of Mercury (NAS-NS-3026)

Basic Books, Inc.

O. R. Frisch, "Atomic Physics Today," $4.50

Duell, Sloan and Pearce, Inc.

K. F. Gantz, "Nuclear Flight," $4.00

S. Naft, R. de Sole, "International Conversion Tables," $7.50

Harper and Brothers

G. Gamow, "Biography of Physics," $4.95, *April, 1961*

International Atomic Energy Agency

"Selected Topics in Radiation Dosimetry," 600 pp. *May, 1961*

"Small and Medium Power Reactors," vol. 2, 600 pp, *May, 1961*

Review Series

No. 9—Comments on Some Aspects of Nuclear Power, *April, 1961*

No. 10—Radiation in Agricultural Research and Practice, *May, 1961*

No. 11—Powder Metallurgy in Nuclear Reactor Construction, *May, 1961*

No. 12—The Packing, Transport and Related Handling of Radioactive Materials, *April-May, 1961*

Biographical Series

No. 3—Nuclear Propulsion, *April, 1961*

No. 4—Manual of Safe Operation of Critical Assemblies and Research Reactors, 100 pp, $1.50, *May, 1961*

No. 5—Radioactive Waste Into the Sea, *May, 1961*

No. 6—Safe Transport of Radioactive Materials, *April-May, 1961*

Interscience Publishers, Inc.

E. Glueckauf, ed., "Atomic Energy Waste: It's Nature, Use and Disposal," 432 pp, $14.00

W. R. Harper, "Basic Principles of Fission Reactors," 288 pp, $7.50

A. R. Kaufmann, ed., "Nuclear Reactor Fuel Elements: Metallurgy and Fabrication"

R. E. Marshak, E. C. G. Sudarshan, "Introduction to Elementary Particle Physics," 212 pp, $2.50

A. B. McIntosh, T. J. Heal, "Materials for Nuclear Engineering," 400 pp, $11.85

D. M. Ritson, "Techniques of High Energy Physics," 544 pp, $16.75

S. M. Stoller, ed., "Fuel Reprocessing," vol. 2 of Reactor Handbook, 2nd ed.

The Macmillan Company

Bethelot, "Radiations and Metter," $5.75

O'Sullivan, "Prospective Construction in a Nuclear Age," 2 vol., $25, *May, 1961*

J. M. Valentine, "Atomic Physics," *April 3, 1961*, $1.95

McGraw-Hill Book Co.

R. L. Chase, "Nuclear Pulse Spectrometry"

M. A. Schultz, "Control of Nuclear Reactors and Power Plants," 2nd edition, $12.50, *March, 1961*

Oxford University Press

J. H. Sanders, "Fundamental Atomic Constants," $1.60, *March, 1961*

Pergamon Press, Inc.

B. S. Dzhelepov, L. K. Peker, "Radioactive Nuclei Decay Schemes"

Philosophical Library, Inc.

W. D. Allen, "Neutron Detection," $10.00

J. Blakey, M. Hutton, "Engineering Mathematics," $10.00

F. Gaynor, "Aerospace Dictionary," $6.00

F. Hinman, "Impact of the New Physics," $6.00

Prentice-Hall, Inc.

G. Gamow, "The Atomics and Its Nucleus," paperbound, $1.95; clothbound, $3.75, *April 15, 1961*

R. L. Murray, "Introduction to Nuclear Engineering," 2nd edition, 416 pp, $12; text edition for classroom adoption, $9

Princeton University Press

D. Billington, J. H. Crawford, "Radiation Damage in Solids," 425 pp, $12.50

C. N. Yang, "Elementary Particles," 80 pp, $2.50, *May, 1961*

Row, Peterson and Co.

S. S. Schweber, "An Introduction to Relativistic Quantum Field Theory," 840 pp, $11.50, *May, 1961*

Simmons-Boardman Books

M. W. Jervis, "Nuclear Reactor Instrumentation" in the Nuclear Engineering Series of Monographs, 96 pp, $2.95

R. G. Palmer, A. Platt, "Fast Reactors," in Nuclear Engineering Series of Monographs, 102 pp, $2.95

E. N. Shaw, "Reactors of the World," (2nd series) $3.50

All Nuclear Engineering Monographs published to date will be available this spring in two-volume cloth-bound edition, $26

University of California Press

M. A. Melkanoff, J. S. Nodvik, D. Saxon, D. G. Cantor, "Program for Elastic Scattering Analyses with the Nuclear Optical Mode," $4.50

D. Van Nostrand Company, Inc.

J. G. Beckerley, ed., "Power Reactor Technology," 417 pp, $11.25

C. S. Cook, "Modern Atomic and Nuclear Physics"

J. Kohl, R. D. Zetner, H. R. Lukens, "Radioisotope Applications Engineering," 512 pp, $12.50, *April, 1961*

J. J. Livingood, "Principles of Cyclic Particle Accelerators," 435 pp, $10.75, *June, 1961*

John Wiley and Sons, Inc.

R. M. Eisberg, "Fundamentals of Modern Physics," 768 pp, $10.50, *April, 1961*

G. Murphy, "Elements of Nuclear Engineering," 224 pp, $7.50, *April, 1961*

D. J. Rose, M. Clark, Jr., "Plasmas and Controlled Fusion," published with MIT Press, 600 pp]

A. H. Snell, ed., "Nuclear Instrumentation and Methods," 944 pp, $12

F. H. Spedding, A. H. Daane, ed. "Rare Earths"

Yearbook Publishers

T. Fields, L. Seed, "Clinical Use of Radioisotopes," 2nd ed., 475 pp, $10.50

O. Glasser, "Medical Physics," vol. 3, 754 pp, $25

Books of Current Interest

Nondestructive Tests in the Field of Nuclear Energy STP 223

A symposium containing 42 papers makes available previously classified material accumulated over a 15 year period. Four main topics: Reactor Components, Fuel Assemblies, Survey Lectures, and Miscellaneous cover various techniques—eddy current, ultrasonic, radiographic, electrode potential, thermal test, helium leak test, optical, and photometric—for inspection of reactors, components and related material for nuclear plants. **Well illustrated. 420 pages, Cloth bound, $10.00.**

The Effect of Radiation on Materials—Vol. III STP 233

This volume covers dosimetry techniques; radiation facilities and techniques; radiation effects. All information is based on new data. **Thirteen well illustrated papers with extensive bibliographies. 168 pages, Hard cover, $4.25.**

Applied Radiation and Radioisotope Test Methods STP 268

This volume presents some unique potentialities of radioisotopes in testing procedures and analysis. Twelve papers give applications in metallurgy, soil analysis, organics and cement. **Illustrated, extensive bibliographies. 112 pages, Hard cover, $3.75.**

Materials in Nuclear Applications STP 276

Included are papers dealing with Ceramics in Nuclear Energy; Industrial Water for Reactor Use; Post-irradiation Effects in Polymers; and Radiation Effects and Dosimetry. **Illustrated. Thirty papers. 344 pages, Hard cover, $8.25.**

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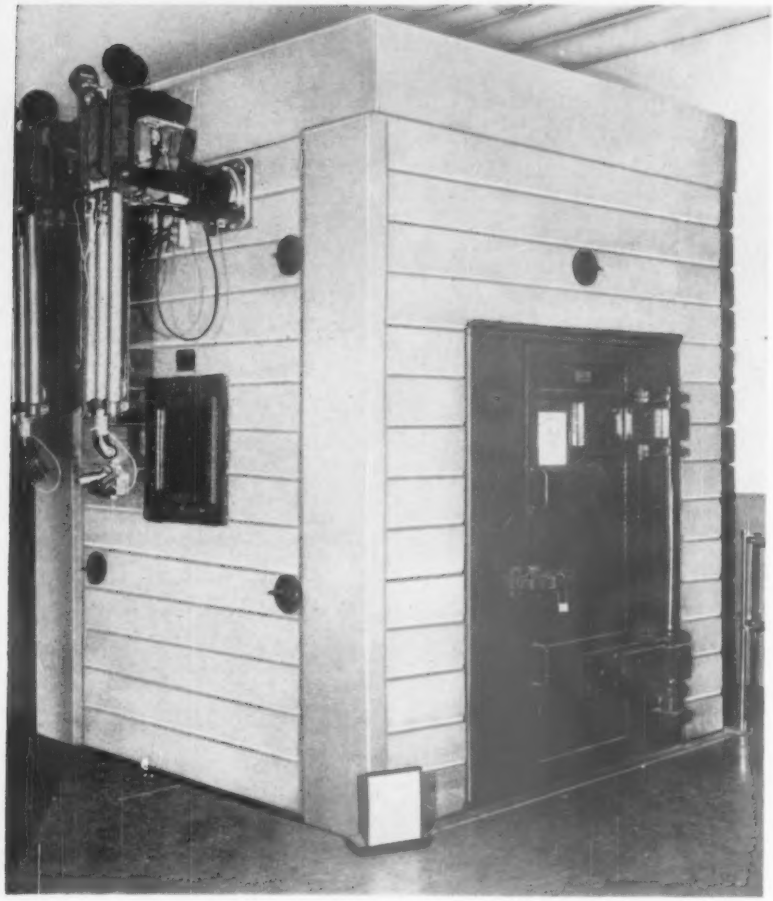

Prefabricated Hot Cells

For laboratory work at intermediate radiation levels complete prefabricated-hot cells (above) are now being sold on an installed and ready-to-operate basis at the customer's site. The hot cell comes complete with two AMF manipulators, filter-ventilating system, eight 4-in. cylindrical access ports with plugs, wide-view (120 deg) shielding window, swinging door and interior lighting; all the customer has to do is provide a suitable level location and a discharge duct for the 250-cfm filter-ventilating system. Measuring inside 5 × 6 × 10 ft, the hot cell has precast, reinforced high-density (235 lb/ft³) concrete walls that measure 15–20 in. thick. The door, made of lead and steel, is equivalent to a thickness of 5 in. of lead. Optional are stainless-steel floor liner and wainscoting, fire-extinguisher system, sliding pass-through devices, heavy-duty manipulators and stainless-steel working surface.—Ray Proof Corp., Stamford, Connecticut.

Cold-Cathode Counter Tube

The Z302C, a cold-cathode, gas-filled decade counter tube gives an output pulse of such magnitude that interstage coupling amplifiers are not needed. Also in this family of tubes are the types Z303C, similar to the GC10B and 6802, and the Z502S similar to the GS10C and 6476. The Z303C is a bidirectional decade-counter tube and the type Z502S is a bidirectional decade selector tube. All three types operate at speeds up to 4 kc. Indication is by an orange-red glow discharge at the end of the electrodes.—Amperex Electronic Corp., 230 Duffy Ave., Hicksville, N. Y.

Plastic Glove Box

Glove box made of ⅜-in. thick linear polyethylene has clear acrylic plastic window measuring 12 × 26 in. The plastic surfaces, which are smooth and nonporous, withstand strong, concentrated acids and solvents. Because of its size (17-in. wide, 28-in. long, 18-in. high at back) and lightness, the glove box can be easily moved to decontamination areas.—American Agile Corp., P. O. Box 168, Bedford, Ohio.

Pulse Light Source

Nanosecond pulse light source (PEK 118) (above) has a 100-pps repetition rate. The size of the light spot is a disk 0.10 in. in diameter. A number of light sources can also be excited in an array with the time jitter between pulses less than 0.2 nanosec.—PEK Labs., Inc., 4024 Transport St., Palo Alto, Calif.

Butyl Dry-Box Gloves

10 times less permeable to gases and moisture as neoprene gloves, these butyl dry-box gloves are resistant to concentrated acids, solvents and ketones. The gloves are made of one piece and are seamless.—CAEMCO, P. O. Box 3693, Jacksonville 6, Florida.

Zircaloy Tubing for Fuels

Zircaloy-4 seamless tubing has small rate of thermal-neutron absorption (0.18 barns cross section) and resists corrosion by heat transfer media; it resists corrosion by water at 750° F, by fused sodium at 1,200° F, and by heavy water. Thus it is particularly promising for fuel element cladding. The tubing comes in sizes ranging from 0.0315 to 0.625 in. dia.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.

Research LINAC

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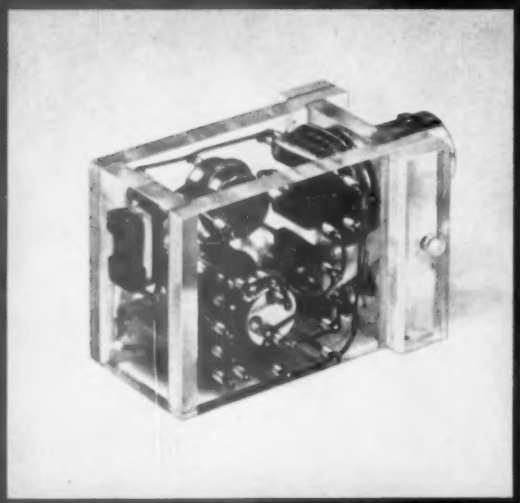

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programs: Operating in a radiation environment is a many faceted problem that offers challenge and growth to many kinds of engineers and scientists in our Nuclear Electronics Laboratory. They are contributing to such projects as: simulating radiation environment to study the radiation resistance of electronic components and systems; the design of LINACS, producing either electron beams, gamma rays or neutron pulses, uniquely adapted to current needs in radiation research, effects testing, medical therapy, sterilization, industrial processing and radiography; radiation detection and measurement with such devices as the Hughes charged particle detector; and mobile remote handling equipment, such as the MOBOT®.

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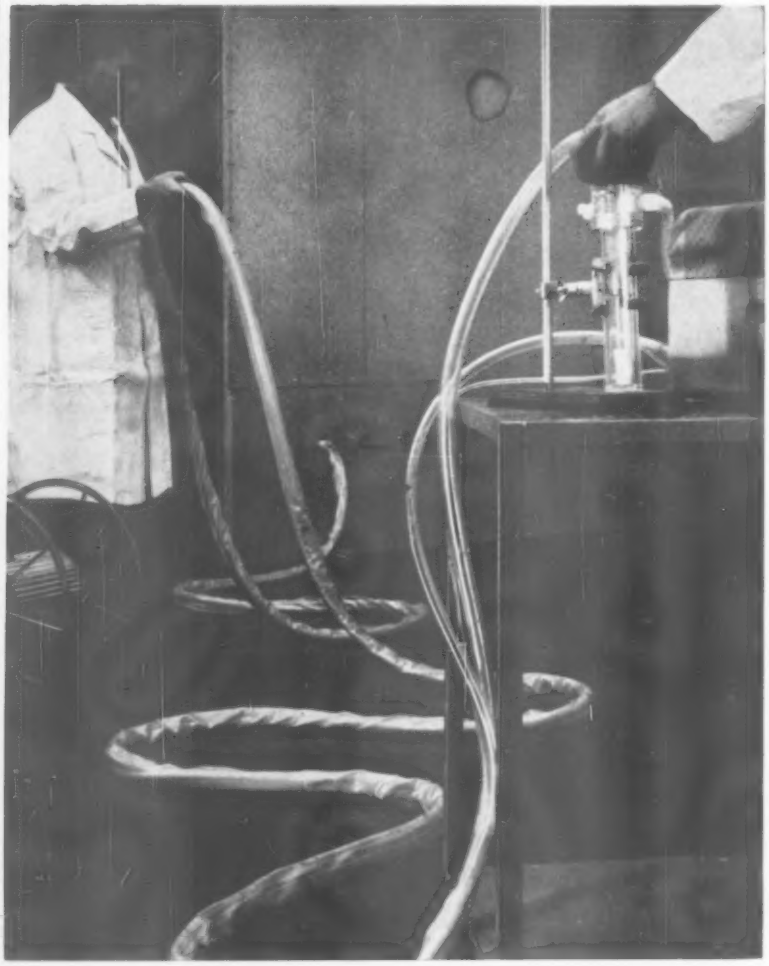
Castings for Manipulator

Investment castings are used in the master handle and slave end of AMF's redesigned master-slave manipulator.

(*Continued*)



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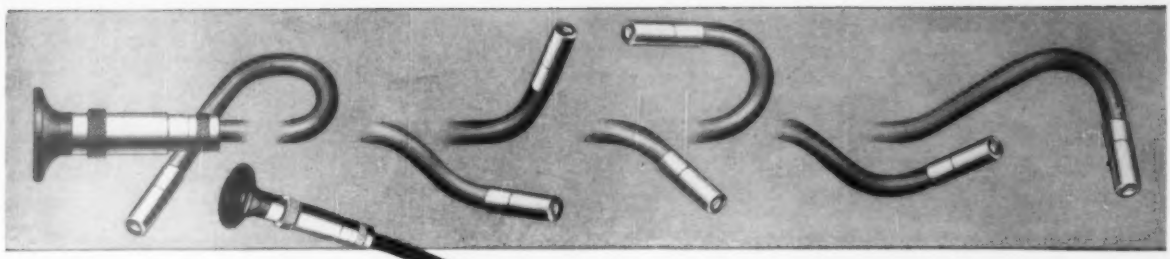

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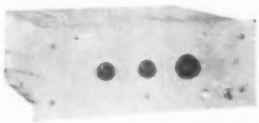

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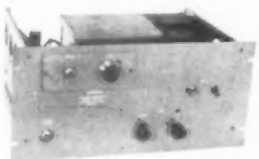

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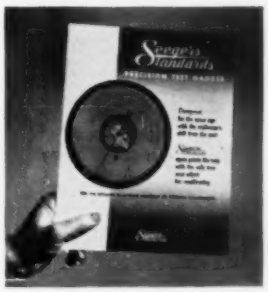

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Most work is on an individual rather than team basis, and staff members may choose and develop their own basic research topics as part of the Laboratories' internally-sponsored program. Background on the doctoral or equivalent level is required.

*

Fields of particular interest to the Laboratories include theoretical nuclear reactor physics, electronic physics, solid state physics, physical chemistry, and advanced nuclear engineering. Facilities and assistance are available for numerical computation and experimental work. Publication and close contact with related university research are encouraged.

*

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Products and Materials

Department starts on page 116

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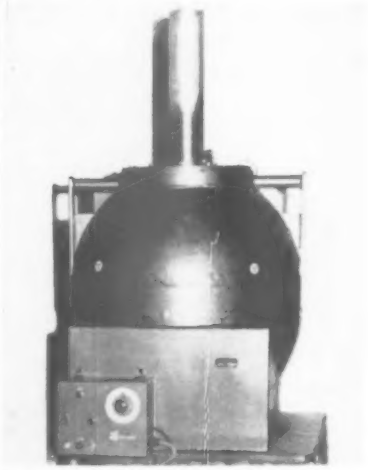
Irradiator with Co^{60} and Cs^{137} Sources



IRRADIATOR can be used to irradiate small animals and biological samples or for chemical and electronic experiments and tests of materials.—U. S. Nuclear Corp., 801 N. Lake St., Burbank, Calif.

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Pulse Generator

Model 414 Calibration Pulser supplies nanosecond and microsecond pulses. Decay times are in 10 steps from 3 mμsec to 100 μsec; amplitude ranges are in 11 steps from 1-mv full scale to 100-volts full scale. Internal standard-cell calibration is included.—Radiation Instrument Co., P. O. Box 733, Silver Spring, Maryland.

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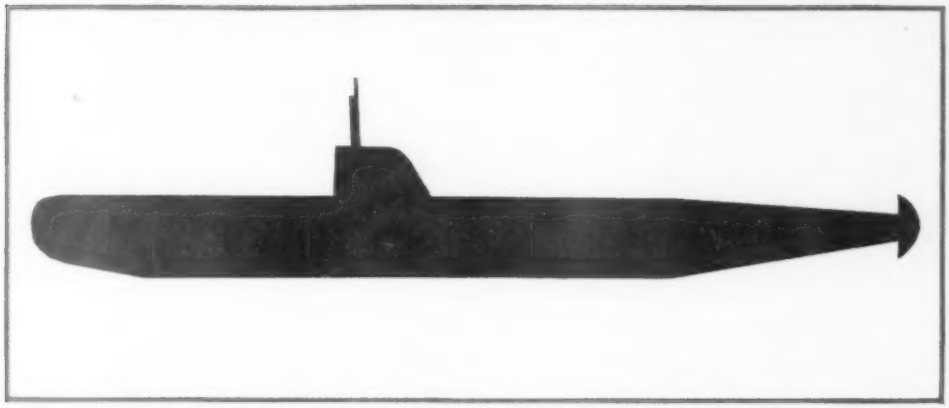

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For more information on how Hall Laboratories can be of assistance to you, write or phone: Nuclear Power Division, Hagan Center, Pittsburgh 30, Pa.

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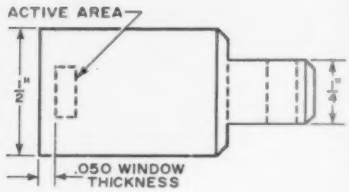

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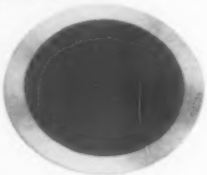
A wide variety of highest quality—economically priced G-M tubes are in stock—produced for U.S. Radium for exclusive sale in the United States by Electronic Associates Limited of Canada. Of particular interest is type EA-3EW, a 1⅛-in. diameter end window, organic-quenched tube with standard four prong base; operating at about 1200—1250V, greater then 350V plateau, average 3 per cent/100V slope and a life of over 500,000,000 counts. Additional G-M tubes described in data sheet available on request.

uranium oxide alpha calibration sources



Uranium oxide uniformly, quantitatively deposited on stainless steel discs and protected by an acrylic lacquer against mild abrasion, are available from stock.

	302 SS, 0.032-in. Thick Discs	
	2⅜-in. Diameter	1-in. Diameter
Active Diameter	2 in.	⅞ in.
Activity (± 20%)	1,000 cpm	1,000 cpm
	10,000	5,000
	25,000	

No AEC license required.

Special sizes fabricated to order.
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united states radium corporation

MORRISTOWN, N. J. | Offices: Chicago, Illinois and North Hollywood, Calif. Subsidiaries: Radelin Ltd., Port Credit, Ont., Canada and U.S. Radium Corp. (Europe), Geneva, Switzerland.

Products and Materials

Department starts on page 116

Portable Counting System

SM1 sample monitor (above) measures radioactivity of samples with low energy in nuclear plants or other locations where the background count is high. The instrument contains a lead castle and end-window geiger counter as well as a two-range linear ratemeter for easy reading and an electromechanical register. All-transistor circuit ensures compactness, reliability and low-power consumption.—E.M.I. Electronics Ltd., Hayes, Middlesex, England.

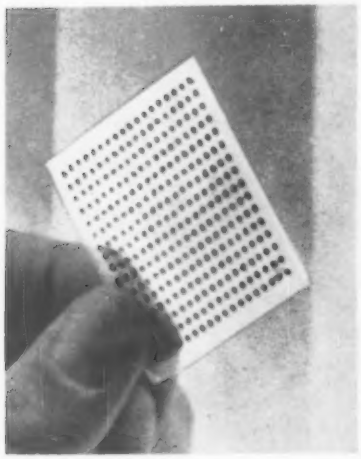
Electronic Timer

Glow-tube timer, the N-804, is a preset and elapsed electronic timer with a 60-cycle controlled-time base and a maximum time storage of 10,000 sec. Time resolution is to the nearest second on times longer than 1,000 sec. Power requirements are 115 volts, single phase, 60 cycle, 75 watts.—Hamner Electronics Co., Inc., P. O. Box 531, Princeton, New Jersey.

G-M Scaler With Transistors

Model E-115 (above), to be used with low-voltage halogen-quenched G-M detectors, has transistor circuitry. Conventional cold-cathode counting tubes record and display the incoming Geiger pulses. The combination of transistors and cold-cathode counting tubes leads

to an absolute minimum of heat and ensures reliable trouble-free operation. —Radiation Equipment and Accessories Corp., Lynbrook, N. Y.



Film Memory for Univac

The Univac 1107 Thin Film-Memory Computer is the first of the commercially available electronic computers to use magnetic film memory (above). This solid-state data-processing system accesses its film memory more than 10^6 times per second in normal operation; its two large banks of core memory are accessed 500,000 times per sec. In addition the system uses a ferrite-core memory of 16,384–65,536 words. The thin film consists of a ferromagnetic film made by vapor deposits of iron, nickel, cobalt or other ferromagnetic metals on a thin glass plate.—Remington Rand Univac, 315 Park Ave. South, New York, N. Y.

Tritium Self-Luminous Paint

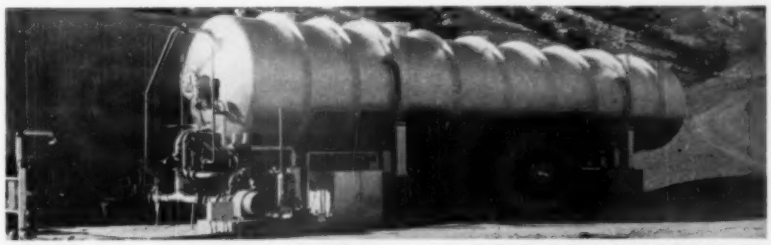
Following the AEC's decision to allow over-the-counter sales of artificially produced radioactive materials, Lumichron, a tritiated self-luminous paint has come on the market. For watch dials, Lumichron has two claimed advantages over conventional radium dials: it has a greater initial brightness and it retains the brightness for a longer period.—New England Nuclear Corp., 575 Albany St., Boston 18, Mass.

Ionization Chamber

Developed for measuring neutron fluxes (10^9–10^{14} n/cm²/sec) in nuclear rockets and ramjets, the high-temperature, uncompensated ionization chamber has an annular construction for internal forced-air cooling. The chamber, designed for 1,000 hr of trouble-free operation, has high vibration and shock tolerance limits because of its rugged, all-welded, stainless-steel construction. The high-temperature extension leads are 25 ft of stainless-steel-sheathed MgO-insulated wire. The operating life expectancies range from 33 yr at 10^{10} n/cm²/sec to 29 hr at 10^{14}.—Marquardt Corp., 16555 Saticoy St., Van Nuys, Calif.

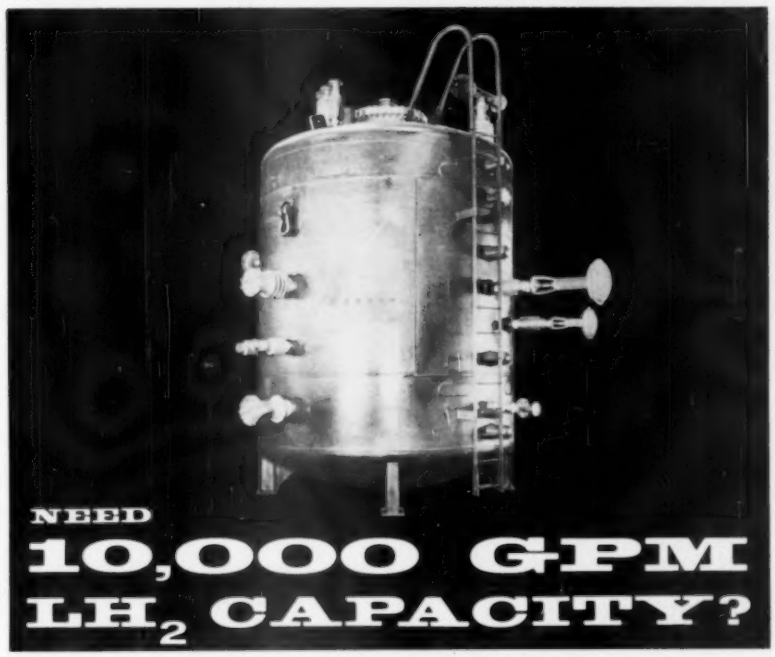
Semiconductor-Detector Amplifier

Complete with an integrated low-noise, high-gain, charge-sensitive preamplifier, a main amplifier and stable biased postamplifier, the Model SS-200 also contains a dual-range bias supply for semiconductor detectors. The detector bias supply has a range of 0–10 volts for fission-fragment detectors and 0–200 volts for charged-particle detectors. In addition, a built-in precision mer-



28,000 GAL. STORAGE DEWAR BUILT BY STEARNS-ROGER.

7,000 GAL. LH_2 DEWAR BY STEARNS-ROGER FOR MISSILE COMPONENT TEST.



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ONE LOOK
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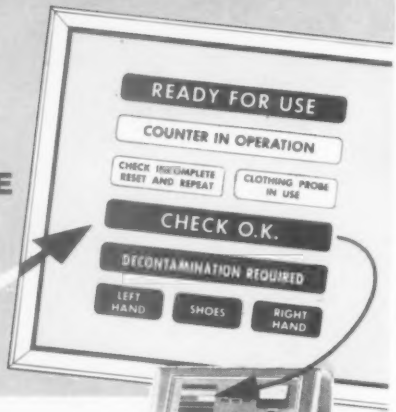


ONLY T/A HAND & SHOE MONITORS offer this outstanding feature!

MODEL HSM-10A provides completely automatic detection and measurement of beta-gamma contamination on the back and palm of each hand and the bottom surfaces of both shoes. No skill is required in its operation. The user simply follows the instructions on the illuminated multi-colored panels on the front of the instrument. The Model HSM-10A employs the decade scaling principle and offers an unusually wide range of warning levels, thus serving any health physics requirement. An external clothing probe with rate meter read-out and speaker is included.

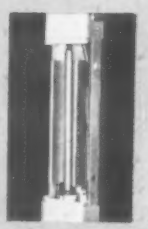
WRITE FOR BULLETIN NO. 167

Another T/A exclusive...

Warning Lights on T/A PORTAL MONITOR locate contamination QUICKLY!

MODEL PPM-8 provides a quick efficient method of "head to toe" monitoring of personnel entering or leaving a controlled area. It features red warning lights, one at each of the 8 detectors, which enable the user to localize quickly the area of beta/gamma contamination.

WRITE FOR BULLETIN NO. 168



180° lead shielding around each detector minimizes the background count.

LIM-18 LAUNDRY INSPECTION MONITOR

A specially designed instrument for monitoring clothing and equipment worn in beta/gamma contaminated areas. 180° lead shielding around each detector increases the sensitivity of the instrument.

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TA TECHNICAL ASSOCIATES

Instrumentation for Nuclear Research

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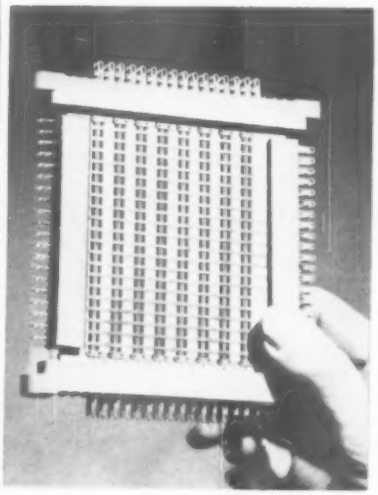
Products and Materials

Department starts on page 116

cury-wetted relay pulse generator makes simple calibration and system checking possible.—Instrument and Development Products Co., Inc., 355 W. 109th Place, Chicago 28, Ill.

Gamma-Gaging Equipment

New noncontact, nondestructive gamma-gaging systems that include a gamma source, a detector and electronic presentation in chart or digital form have high penetration capabilities, fast response and good resolution.—Radio Corporation of America, Industrial Controls Div., Building 15-1, Camden, N. J.



Thin Film-Memory Planes

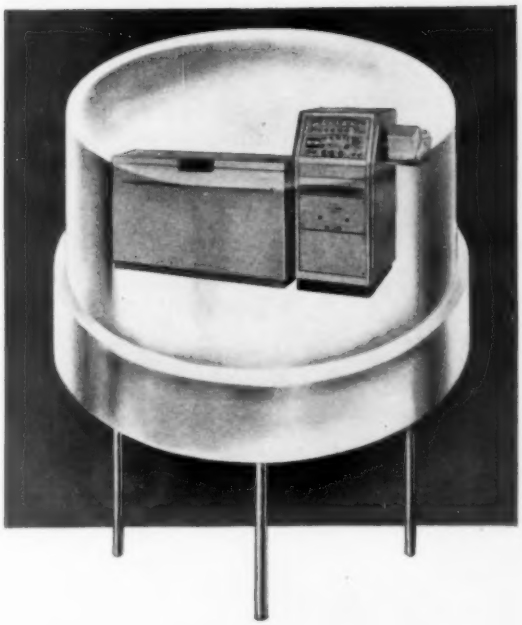
For faster memory systems, film memory planes (Type BIP-1000) 2,000 Angstroms thick have been made that store 20 words of 8 bits each. These memory planes (above) contain depositions of a nickel-iron alloy vapor on a glass substrate; these are then sandwiched between two printed-circuit boards containing read, information and sense conductors. The units have cycle time capabilities of 0.2 μsec.—Burroughs Corp., Electronic Tube Div., P. O. Box 1226, Plainfield, N. J.

Flame Potentiometer

To measure elements and monitor impurities in them continuously in the part per billion and part per million range, one can use this new flame potentiometer. The instrument consists of

It's What's Inside That Counts!

Packard Tri-Carb Liquid Scintillation Spectrometer



Accurately and automatically achieves the best experimental results presently possible utilizing the latest radioactive tracer counting methods for such materials as proteins, lipids, amino acids, tissue, body fluids, aqueous solutions, tritiated water, and carbon dioxide.

In the first six months after the transistorized Tri-Carb replaced its vacuum-tube predecessor, more than a hundred installations were made in 15 countries on four continents. More samples of tritium, carbon-14, and other alpha- and beta-emitters are now being counted in the Packard Tri-Carb Spectrometer than in any other instrument.

You will be interested in our latest bulletin, which shows "what's inside" the transistorized Tri-Carb Spectrometer that makes it count so well . . . so reliably.

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THE RADIOCHEMICAL CENTRE
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two parts: an optical unit that houses the sample manifold, burner, manochromator and photomultiplier, and a control panel that contains the high-voltage supply amplifier, automatic standardizing system, sample sequence selector and recorder. When the sample is placed in the burner the photomultiplier detects the radiation emitted by impurities.—Waters Associates, 45 Franklin St., Framingham, Mass.

Solid-State Detector

The detector (above) has a single-crystal high-purity *p*-type silicon (resistivity ranges >10,000 ohm-cm material) with a shallow *n*-type surface diffused layer. The alpha-particle energy detection range is 0.5–10 Mev with maximum operating voltages of 100 volts or more. The resolution of the detectors is <4%. Signal-to-noise ratio is rated at 15 to 1; but many of the detectors show a 50 to 1 ratio.—Semi-Elements, Inc., Saxonburg Blvd., Saxonburg, Pa.

1-kc Decade-Counter Module

Plug-in decimal decade-counter module (DC-113) that uses a Beam X decade switch has input circuitry that eliminates tubes or transistors for activating succeeding decades. The unit will directly drive indicator tubes, printers, etc., without decoders or amplifiers.—Burroughs Corp., Electronic Tube Division, Box 1226, Plainsfield, N. J.

OMISSION. We inadvertently left out the manufacturer of "Robot with a Memory" in April. The company is Consolidated Controls Corp., Bethel, Conn.

"Why do they still make 'em like they used to?"

In 1876 this great Corliss steam engine was set into motion by President Grant before thousands of astonished guests at the opening of the Centennial Exhibit in Philadelphia. Thirty-nine feet in height and weighing seven-hundred tons, the Corliss giant, with its twin 750 horse-power engines, was able to turn the fifty-six ton, thirty-foot gear fly-wheel at a speed of thirty-eight miles per hour—thus producing operational power to all the machine exhibits.

This product of man's ingenuity and mechanical prowess in the formative years of industrial power was indeed a giant in size, weight, imagination and . . . *complexity and cost!* Today we are building nuclear power plants more powerful than Mr. Corliss could ever have imagined. Yet, despite the passage of time, the problems of giant-size complexity and giant-size cost remain with us. Why do they *still* build 'em like they used to? The answer is easy. In the early years of any new technology, equipment is intricate and costly.

And so it is today in the nuclear field. For example, one-third of the capital cost of the reactor portion of a nuclear power plant can be attributed to the same complex and costly components as in the Corliss steam engine—pumps, valves and heat exchangers. Simplification and cost reduction in this area of technology alone would be a giant step in the nuclear industry's drive toward economic competitive power. In its July issue NUCLEONICS will make an important contribution to the progress of the nuclear industry by publishing a major special report on Reactor Components. This 32-page editorial report will deal with what we know today in the technology of nuclear hardware and where we need to go in the future.

THE JULY REACTOR COMPONENTS SPECIAL REPORT

Specifically, the report will cover three major reactor components: pumps, valves and heat exchangers. In preparing this timely report NUCLEONICS surveyed reactor fabricators, systems-designers and reactor operators and held personal interviews with a dozen component manufacturers in many cities. These surveys and interviews were the basis for developing a series of articles written by authorities in the field. The articles will cover:

Pumps:
Comparison of Canned & Controlled Leakage Pumps
Waste Handling Pumps
Pumps for Reactor Plant vs. Turbine Generator Plant
Controlled Leakage Pump Seals

Heat Exchangers:
Criteria Used for Selection of Heat Exchangers
Thermal, Mechanical, and Fabrication Design Factors
Developments Needed in the Heat Exchanger Field

Valves:
Guide Post to Valve Selection
Service Experiences
Forecasting Valve Design Requirements

REFERENCE TABLE

An important part of the July Components Report will be a two-page reference table for each of the above three sections. Each table will list a complete description of the particular component in each of the fifty existing water-cooled reactors.

A WINNING COMBINATION

The July NUCLEONICS 32-page special report will pinpoint your audience. The reader most interested in this report will be the person who selects components of all types. The stage will be set for a healthy sales climate with the winning combination: YOUR PRODUCT and NUCLEONICS.

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NUMEC is the primary commercial firm in the scrap recovery field. Experience includes recovery work with such materials as uranium metal, oxides, dispersions, and alloys; urania-thoria mixtures and solid solutions; urania-zirconia solid solutions; urania-beryllia and many others.

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Products and Materials

Department starts on page 116

LITERATURE AVAILABLE

Shielding Windows. 12 pp.; Ray Proof Corp., 843 Canal St., Stamford, Conn.

Power Transistor Handbook. Motorola, Semiconductor Products Division, Inc., 5005 E. McDowell, Phoenix, Ariz.

Magnets. 32 pp.; Varian Associates, Palo Alto, Calif.

Electromagnets & Power Supplies. 2 pp.; Harvey-Wells Nuclear Corp., 43 Kendall St., Framingham, Mass.

Carbon Dioxide Manufacturing System. 4 pp.; Louis De Markus Corp., 3080 Main St., Buffalo 14, N. Y.

Valves for Handling Radioactivity. 2 pp.; Royal Research Corp., 11824 Dublin Blvd., Hayward, Calif.

Indicating & Transmitting Rotameter. 4 pp.; Fischer & Porter Co., Warminster, Pa.

PNP Germanium Power Transistor. 4 pp.; CBS Electronics, Semiconductor Operations, Lowell, Mass.

Silicon Power Transistors—Application Guide. 26 pp.; Radio Corp. of America, Somerville, N. J. 50 cents.

Displacement-Type Liquid Level Controls. 12 pp.; Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.

High Voltage Pentode. 4 pp.; Victoreen, Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio

Dual Gas Flow Counter. 1 p.; Atomic Accessories Inc., 811 W. Merrick Rd., Valley Stream, N. Y.

Temperature Probes and Pressure Transducers. 6 pp.; Rosemount Engineering Co., 4900 W. 78th St., Minneapolis 24, Minn.

Magnetohydrodynamics. 10 pp.; MHD Research, Inc., P. O. Box 1815, Newport Beach, Calif.

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Division Director of scientific group doing advance work in radiation shielding, atomic defense engineering, decontamination, radioisotope tracer techniques, handling and storage of reactor components.

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Department N

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INDUSTRY NOTES

● Two companies have joined capabilities to develop light-weight radiation shielding: **Michigan Chemical Corp.**, Saint Louis, Michigan and **Haveg Industries, Inc.**, Wilmington, Del. Michigan Chemical's rare-earth and thorium div. will work with Haveg's plastics div. to combine known plastics, organic and inorganic fibers and fillers with rare earths. Last September Michigan purchased AEC's large rare-earth ion-exchange facility, which is located within Michigan's plant facilities.

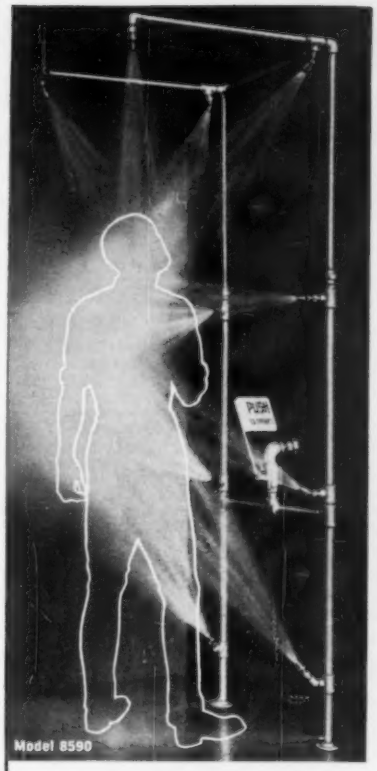
● **Nuclear Materials & Equipment Corp.**, Apollo, Pa., under two contracts, will supply over 29 tons of enriched nuclear fuel to Westinghouse for the second core loading of the Yankee reactor, and for the first loading of the Saxton reactor. SNEC (Saxton Nuclear Experimental Corp.) estimates that the initial fuel supplied by NUMEC will last for 11,000 hours at full power, or $1\frac{1}{4}$ years.

NEW CONTRACTS. The National Aeronautics and Space Administration has awarded **General Electric's Flight Propulsion Laboratory** dept., Cincinnati, Ohio, a contract to study heat-flow characteristics of several working fluids that could be used in spacecraft nuclear power plants—sodium and potassium especially. GE will share the estimated $575,000 project cost with NASA. . . . Research and development of pilot-model components for the proposed two-mile 10–20 Bev accelerator at Stanford University will be carried out by Radio Corp. of America and Sperry Gyroscope Co. under subcontracts totaling $600,000.

NEW BUSINESS. **Radionics, Inc.**, Norristown, Pa., has introduced its new line of gamma-radiographic cameras, sources and equipment. The product will be sold in the U. S. and Canada by **Philips Electronic Instruments**, a division of **Philips Electronic & Pharmaceutical Industries Corp.** Radionics will, however, still independently market its line of nuclear gages . . . **Tracerlab, Inc.'s** reactor monitoring center in Richmond, Calif., will provide radiation monitoring instrumentation for PM-1 Portable Medium Power Plant, designed by Martin Co. for AEC and the Air Force. Tracerlab's system includes two MWP-2P water monitoring systems, a 10-channel area monitoring system, a MAP-1 air particulate monitor and an assortment of air samplers and laboratory equipment. . . . **Davison Chemical Nuclear Materials** plant, Erwin, Tenn., a subsidiary of **W. R. Grace & Co.**, has announced it has commercial quantities of uranium monocarbide, and uranium and thorium dicarbides available. In an initial commercial order for this material from private industry, **Atomics International** div. of North American Aviation Corp. called for 1,500 lb of uranium monocarbide. . . . **Hydro-Aire Co.**, Burbank, Calif., will develop a prototype flow-control system for monitoring the water flow in reactors under an AEC contract. The system must monitor 1,076 channels. The AEC project is the first process-control system to be developed by Hydro-Aire's recently created Electronics div.

FINANCE. **National Distillers and Chemical Corp.'s** titanium and zirconium subsidiary, **Reactive Metals Inc.**, Niles, Ohio, which has shown losses in past years, operated at a profit during the closing eight months of 1960, a company official said. The improvement of earnings resulted from the increase of National's ownership from 33% to 60% of the company. Reactive Metals has announced plans to expand its facilities at Niles into buildings of **Bridgeport Brass Co.** This month, stock holders of National and Bridgeport Brass will decide upon a proposed merger which would combine annual sales of $730-million and assets of approximately $625-million. . . . **New England Nuclear Corp.** announced a five cent dividend on 200,000 outstanding shares on record sales for fiscal 1960. Sales for the period exceeded $725,000 or were 20% above the $600,000 sales of the preceding fiscal period. . . . **Royal Industries, Inc.**, Los Angeles, reports a 13% increase in 1960 sales ($13,390,730) over 1959 ($11,853,616). Net income was $467,583.

ACQUISITIONS. **Raychem Corp.**, Redwood City, Calif., has established a subsidiary in England, **Raychem U. K. Ltd.**, for research, manufacturing and marketing of Raychem's products. The venture is a joint one with **B. X. Plastics Ltd.**, a British plastic manufacturer. Raychem's sales for six months ending Dec. 1960 were reported as $1,950,000, an increase over the previous year's sales of $1,120,108.



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* on some models

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Weight	4 oz.	9 oz.	10 oz.	Available as DCUA, DCMA, DCA, DCMV, DCV, ACV, with zero at center, left or right. Also VU and Db meters.
Accuracy	± 3% of full scale for DC, ± 5% for AC	± 2% of full scale for DC, ± 5% for AC	± 2% of full scale for DC, ± 5% for AC	
Scale Length	1.2"	2.1"	2.7	
Panel Area	0.9 sq. in. (cutout 1.687" x .531")	2.0 sq. in. (cutout 2.656" x .781")	5.5 sq. in. (cutout 3.450" x 1.300")	
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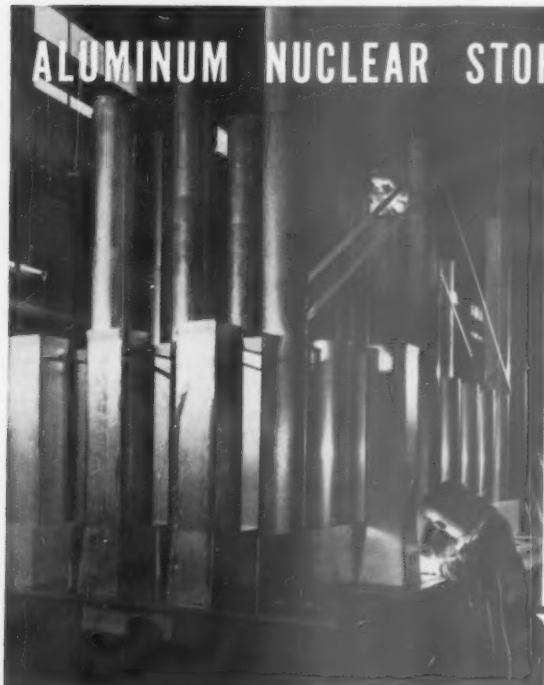

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by CPC

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STURBRIDGE, MASS.

NUCLEAR CALENDAR

May 3–5—Nuclear Space Conference, Gatlinburg, Tenn. (*Gatlinburg Civic Auditorium*). Sponsor: American Rocket Society. Contact: R. L. Hohl, 500 Fifth Ave., N. Y. 36, N. Y.

May 7–10—National Meeting of the American Institute of Chemical Engineers, Cleveland, Ohio (*Sheraton-Cleveland*). Sponsor: AIChE. Sessions include papers on radioactive materials for process control. Contact: J. F. Van Antwerpen, AIChE, 25 W. 45 St., New York 36, N. Y.

May 8–10—13th National Aerospace Electronics Conference, Dayton, Ohio (*Biltmore & Miami Hotels*). Sponsor: Institute of Radio Engineers. Contact: L. G. Cumming, IRE, 1 E. 79 St., New York 21, N. Y.

May 11–13—Annual Meeting of the American Radium Society, Colorado Springs, Colorado (*Broadmoor Hotel*). Sponsor: ARS, 350 Engle St., Englewood, N. J.

May 15–17—Annual Meeting of the Radiation Research Society, Washington, D. C. (*Sheraton-Park*). Sponsor: RRS. Contact: E. L. Powers, Div. of Biological and Medical Research, Argonne National Lab., Lemont, Ill.

June 4–8—American Nuclear Society Annual Meeting, Pittsburgh, Pa. (*Penn-Sheraton*). Sponsor: ANS. Contact: Octave J. DuTemple, ANS, 86 East Randolph St., Chicago 1, Ill.

June 14–17—Eighth Annual Meeting of the Society of Nuclear Medicine, Pittsburgh, Pa. (*Penn Sheraton*). Contact: Samuel M. Turiel, SNM, 430 No. Michigan Ave., Chicago 11, Ill.

June 26–Sept. 1—Gordon Conferences on Nuclear Chemistry, scheduled during the summer at Colby Junior College, New London, N. H.; New Hampton School, New Hampton, N. H.; Kimball Union Academy, Meriden, N. H.; Tilton School, Tilton, N. H. For details and dates, contact: W. George Parks, Director, Univ. of Rhode Island, Kingston, Rhode Island.

June 27–28—Symposium on Radiation Effects on Refractory Fuel Compounds, Atlantic City, N. J. (*Chalfonte-Hadden Hall*). Sponsor: Battelle Memorial Institute. Contact: American Society for Testing Materials, 1961 Race St., Philadelphia, Penna.

NEWSMAKERS

Elda E. Anderson, head of Oak Ridge National Laboratory's education and training section in the Health Physics div., has been named chairman of the American Board of Health Physics. The Board was established by the Health Physics Society last year to standardize requirements for radiation protection specialists—150 applicants have been accredited during the board's first year.

Anderson

Pierre L. Balligand of the Commissariat a l'Energie Atomique will succeed **Hubert de Laboulaye** as Deputy Director General in charge of the department of technical operations of the International Atomic Energy Agency. Balligand, who assumed his duties last month, has been director of research reactor programs for CEA.

Daniel Binder, formerly of Oak Ridge National Laboratory, has joined Hughes Aircraft Co.'s nuclear electronics laboratory as head of the nuclear measurements department.

Harold Brown, director of the Univ. of California's Livermore Laboratory, has been nominated by President Kennedy to direct research and engineering for the Department of Defense. Upon confirmation by the Senate, Brown will succeed Herbert York who also came to the DOD post from the Univ. of California. Brown has been a member of President Kennedy's science advisory committee, the Air Force scientific advisory board, and the scientific advisory committee to the Secretary of Defense on ballistic missiles.

Brown

Louis A. Carapella, formerly of Sylvania-Corning Nuclear Corp. has joined the research div. of General Dynamics/Electronics where he will be responsible for technical liaison within the division and with other divisions within the company.

William R. Corliss of The Martin Co.'s nuclear div. has been appointed consulting editor on propulsion for the Encyclopedia of Science and Technology published by McGraw-Hill Book Co.

James Flack, Lockheed Nuclear Product's chief nuclear engineer, has been appointed to direct all nuclear activities of Lockheed's Georgia div. He first joined the Georgia div. in 1954 as an operations and research scientist, and has directed experimental operations at the Georgia nuclear laboratories where nuclear reactors are made. In the reorganization of Lockheed's nuclear div., T. H. Thomas assumes management of the reactor systems div. under Flack who reports directly to Chief Engineer Art Flock.

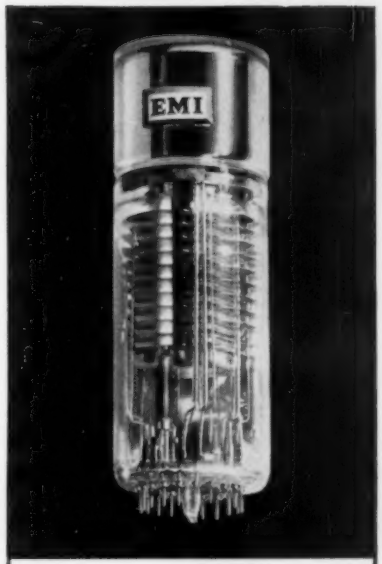
Flack

Arthur W. Flynn, formerly a manager of development and project engineering for Nuclear Development Corp. of America, has taken up his duties as nuclear engineer at Ebasco Services, Inc.

John S. Foster, Jr., has been named director of the University of California's Lawrence Radiation Laboratory, Livermore, to succeed Harold Brown (see left). Foster has been an associate director of Livermore for the past three years. He is a recipient of the AEC's Ernest Orlando Lawrence Memorial Award for his contributions to nuclear weapons development. One of his projects was the development of ion sources for linear accelerators and some basic studies of high vacuum ion pumping. He assumes his post June 1.

Foster

Robert Wayne Houston, professor of chemical engineering at Columbia University, has been named director of the Industrial Reactor Laboratories, Plainsboro, N. J., a research facility owned jointly by ten noncompeting industrial corporations involved in nuclear research. Columbia has one-eleventh share in the use of the laboratories, and



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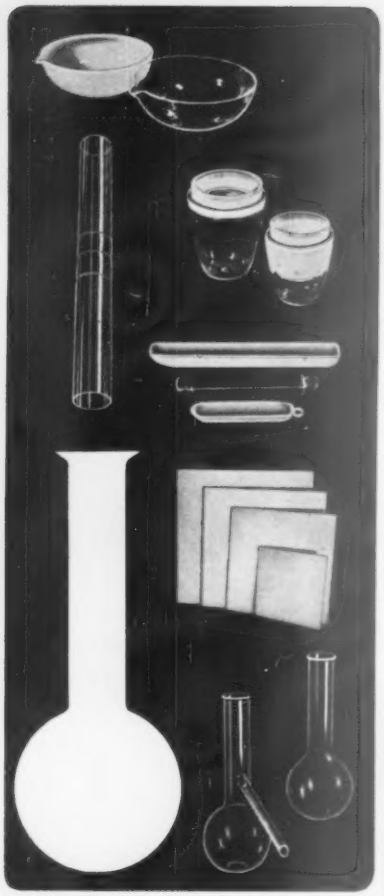

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Newsmakers

Department starts on page 131

recently signed an agreement to operate the facility.

Alvin Jackson, who was engaged in biochemical research for the California Corp., has joined the chemistry staff of Tracerlab, Inc. as part of that company's expansion program in the field of new radioactive chemical compounds for medical and industrial uses.

William J. Jackel, who heads the Albuquerque div. of ACF Industries, Inc., has been elected a vice president of the company. Jackel will continue to head the company's Albuquerque div., which is operated by ACF for AEC, as vice president and general manager.

Mortimer A. Schultz, a 22-year veteran of Westinghouse, and project manager of Westinghouse's WTR since 1956, has left the company to establish a consulting service in Pittsburgh, Pa. He plans to center his service in the field of automatically controlled nuclear power plants, reactor operation, nuclear instrumentation, reactor testing, real and political safety and licensing problems. Schultz, author of "Control of Nuclear Reactors and Power Plants" as well as numerous articles on control of nuclear reactors, may join his capabilities with another specialist in these fields.

Schultz

Bernard B. Smyth, formerly with the Washington law firm of Dow, Lohnes and Albertson, has been appointed an assistant vice president of the General Atomic div. of General Dynamics Corp. and manager of GA's Washington office. He has been assigned responsibility for project development and liaison activities on the East coast and will participate in over-all program planning for GA.

George Welford, who has been a staff member of AEC's health and safety laboratory since 1949, has joined U. S. Nuclear Corp. as director of its laboratory and radiochemical bioassay and environmental testing.

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An Open Letter to Dr. Glenn Seaborg

1961 is a year of crisis for the civilian nuclear power program. This may sound dramatic, but events could easily swing the pendulum in a positive or a negative direction. The purpose of this letter to you is to make some recommendations to you to ensure a positive swing.

We have come a long way in the civilian nuclear power program from its origin in the early 1950's. We've made major advances, for example, in nuclear fuel technology, materials development, understanding of reactor physics, and most important, we have three full-scale plants in operation. We even have several reactor manufacturers who state they are offering nuclear power plants to utilities in certain parts of the country that would produce competitive power.

But, with all this, we are not there yet. In fact, events in 1961 will have a major influence on how quickly we arrive at a truly competitive nuclear-power economy, a national goal that was established back in 1953. For, at the moment, there are several clouds hanging over the industry. In the last year, no new major reactor projects have been committed. In fact, several expected to be committed have either been delayed or canceled. The AEC-industry cooperative reactor building program is at a standstill. There is great uncertainty over the impact of the upcoming Supreme Court decision on the Enrico Fermi plant case. And, relatedly, AEC's proposed reactor siting criteria have met with mixed reaction in the industry.

All of these "shadows" can be dissipated and may well be dissipated in 1961. But what happens depends in large part on the character and the vigor of the leadership shown in Washington. At the moment, there is a vacuum in atomic-energy leadership in the Capital—not surprising in this period of takeover and getting educated by the new Administration. No one individual has moved to the fore to take on the mantle of leadership.

One surprising development is that the chairman of the Joint Committee on Atomic Energy, Rep. Chet Holifield, has turned docile as far as nuclear power is concerned and has said he has no intention of pressing for any particular goals such as he did in the Eisenhower Administration. Rather, he will take any goals that President Kennedy sets and will evaluate the program in light of them.

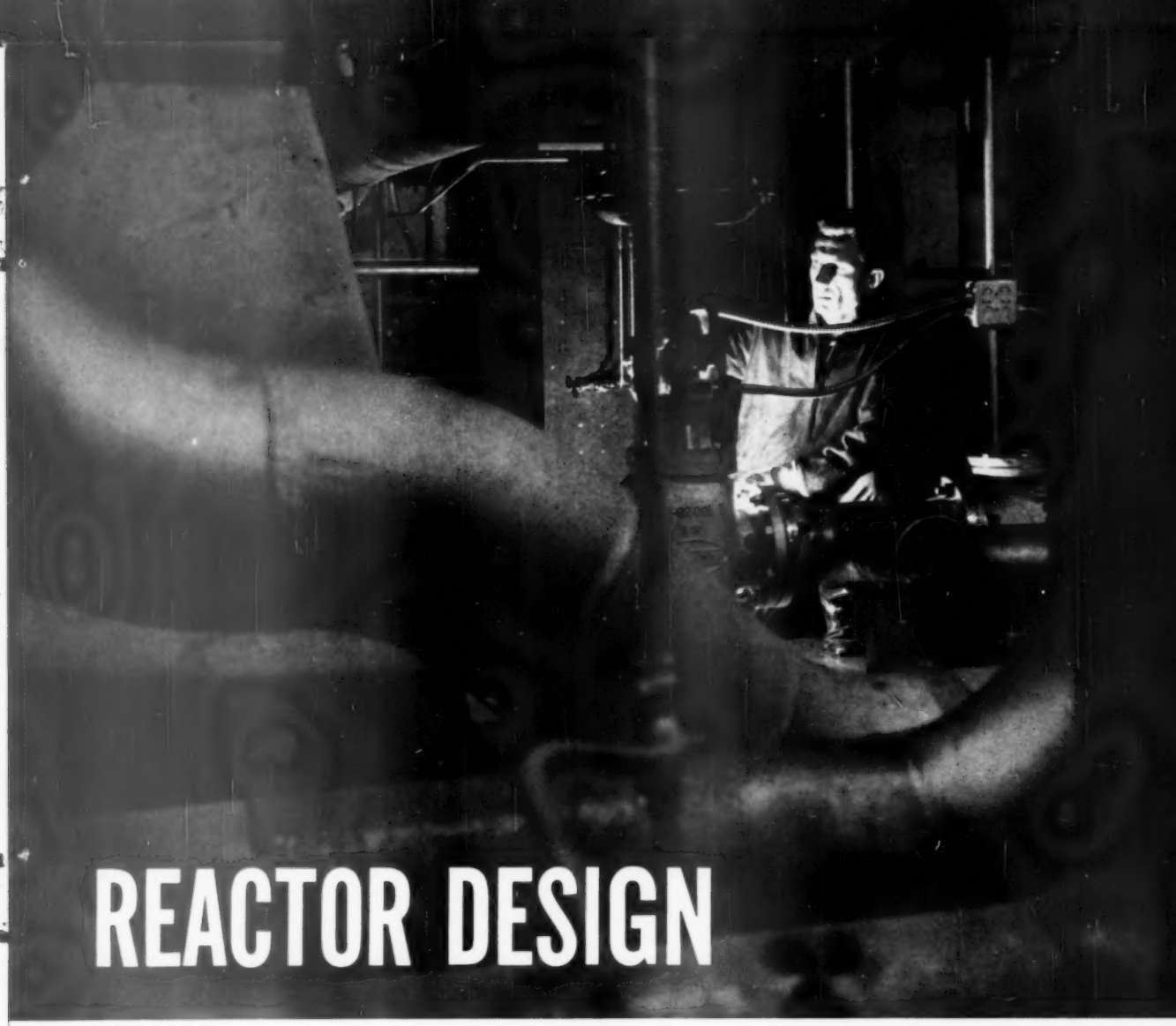
And you, Dr. Seaborg, as the new chairman of the AEC, have not yet had the opportunity to jump into the battle with a flaming torch to ignite a fire under the stalled nuclear-power bandwagon.

But, to dissipate the shadows, some of the fire of yore is indeed needed, specifically as follows:

1. The AEC—the Administration—needs to reaffirm as strongly as possible and as soon as possible its aim to support a strong nuclear power effort to achieve competitive nuclear power in the U. S. before the end of this decade. The need for achieving this goal needs to be spelled out again and again—a goal calling for U. S. world leadership in this field and the production of a new source of economic energy.
2. An aggressive, cooperative U. S.-industry effort to build nuclear power plants must be sold by AEC to Congress and possibly even to industry, perhaps including a capital subsidy plan, for the purpose of assuring the building of plants.
3. The Enrico Fermi fast-breeder case should be viewed in proper perspective. The decision of the Supreme Court will presumably either permit the plant to be operated or not. Whatever the decision, the AEC and the industry need to recognize that the case involves a fast breeder, a very advanced plant, and the decision should have no relevance to the more tested plants, the water types. This case should not be awaited as the be-all and end-all of the reactor business, as some would have it—and as many concerned with reactor siting decisions apparently see it.
4. And, on reactor siting, AEC needs to move quickly to provide clear interpretation of the meaning of its proposed new siting criteria—to provide guidance to the industry on just what it may expect to be able to do and what it may not.
5. And, finally, the message of the importance of the civilian nuclear power program to the U. S. must be carried to all quarters of the U. S. by vigorous "salesmen" who believe in it. The AEC can certainly take the lead in this.

Dr. Seaborg, we know you have only been on the job a short time. But we thought you might, at this early date, welcome some ideas on a program that we feel is vital to the U. S. and the world.

Respectfully,
The Editors of NUCLEONICS



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Experience gained by LNP in the operation and management of America's largest nuclear radiation effects research facility—the U.S. Air Force's Plant 67, on a 10,000-acre site at Dawsonville, Georgia—adds another significant dimension to our ability to design and build reactors to fulfill any defense, scientific, or commercial requirement.

A letter, wire, or phone call will bring a Lockheed Nuclear Products representative to your plant or office to discuss your problems in:

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Write: Nuclear Sales Manager, Lockheed Nuclear Products, 1500 Northside Drive N.W., Atlanta 18, Georgia.

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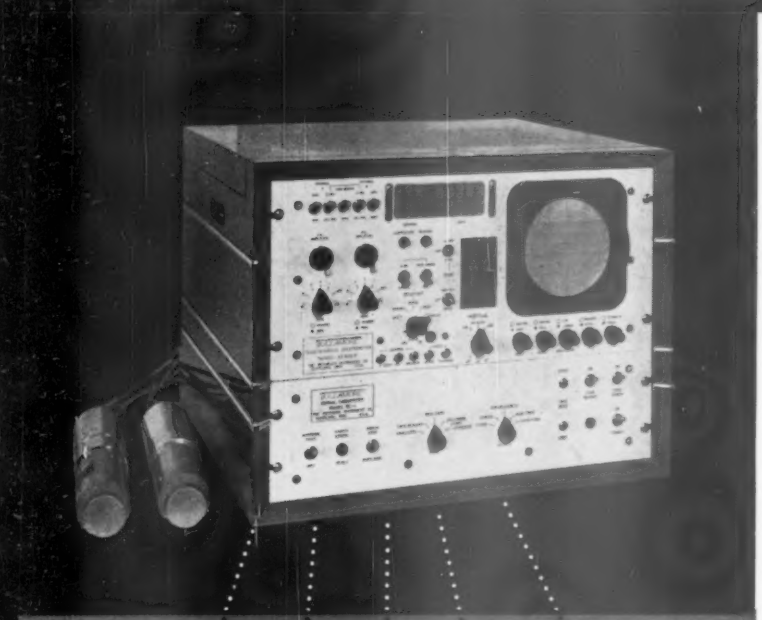

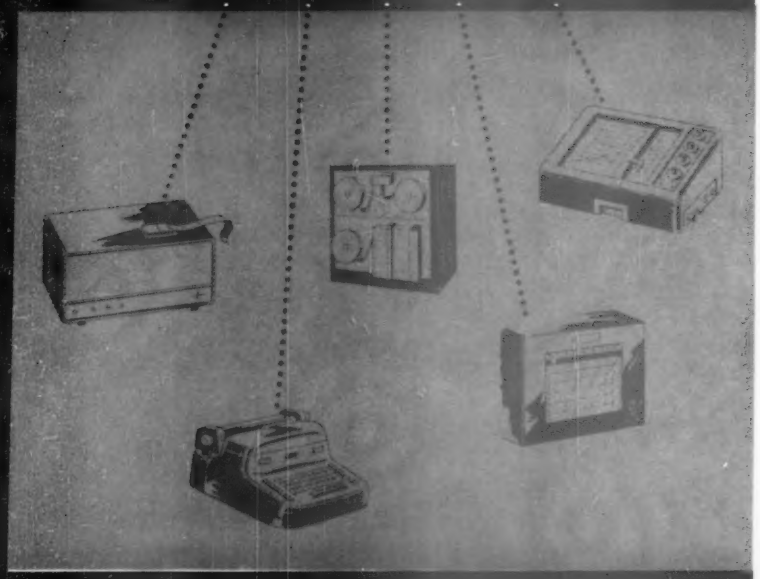

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